



15605/A

FRONT ROW  
Shelf No. 139 Library.

STUDIO MINUENTE LABOREM



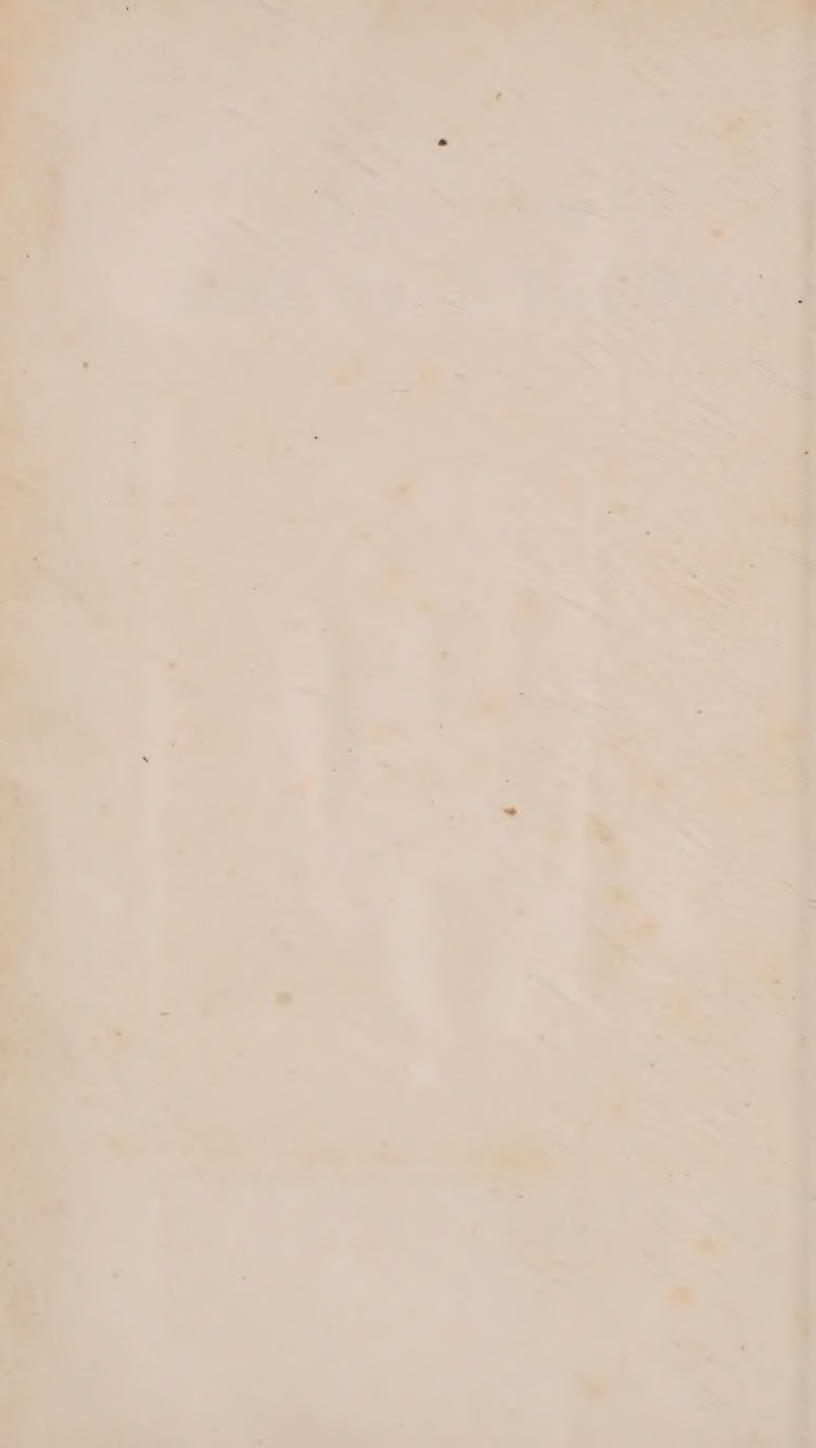
((Macarthur.))

1st Baron Brough Vaux

SURE AND STEADFAST.



CLARK.










TWO DISCOURSES  
OF THE  
OBJECTS,  
PLEASURES, AND ADVANTAGES,  
I. OF SCIENCE:  
II. OF POLITICAL SCIENCE.

BY  
HENRY LORD BROUGHAM, F.R.S.

AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE.



LONDON:  
CHARLES KNIGHT & CO., LUDGATE STREET.  
1846.

# ADVERTISEMENT



The Discourse  
and Advantages  
published as the last  
Library of Useful Knowledge. It was the  
first step in that remarkable advance in the  
instruction of the people by the means of  
cheap books, which was commenced by the  
Society for the Diffusion of Useful Know-  
ledge nearly twenty years ago. The Discourse  
of the 'Object, Plan, and Advantages  
of Political Knowledge' was published as a  
later period as the 'Library of Useful Knowledge'.  
Lord Brougham's 'Political Economy'.  
Both Discourses are reprinted in this volume  
by permission of the noble author, under an  
arrangement with the Society for the Diffusion  
of Useful Knowledge as to the Copyright of



## ADVERTISEMENT.

---

THE Discourse of the 'Objects, Pleasures, and Advantages of Science,' was originally published as the Introductory Treatise to the 'Library of Useful Knowledge.' It was the first step in that remarkable advance in the Instruction of the People, by the means of cheap books, which was commenced by the Society for the Diffusion of Useful Knowledge nearly twenty years ago. The Discourse of the 'Objects, Pleasures, and Advantages of Political Knowledge' was published at a later period as the Introductory Treatise to Lord Brougham's 'Political Philosophy.' Both Discourses are reprinted in this Volume by permission of the noble author, under an arrangement with the Society for the Diffusion of Useful Knowledge as to the Copyright of each.

Printed by W. Crowder and Son, Strand Street, London.

# ADVERTISING

The object of the present volume is to provide a complete and accurate record of the advertising of the United States for the year 1900.

ADVERTISING IN THE UNITED STATES, 1900. By J. W. B. WILSON. New York: The Advertising Bureau, 1900.

This volume is a complete and accurate record of the advertising of the United States for the year 1900. It contains a full and complete record of the advertising of the United States for the year 1900.

ADVERTISING IN THE UNITED STATES, 1900. By J. W. B. WILSON. New York: The Advertising Bureau, 1900.

This volume is a complete and accurate record of the advertising of the United States for the year 1900. It contains a full and complete record of the advertising of the United States for the year 1900.

ADVERTISING IN THE UNITED STATES, 1900. By J. W. B. WILSON. New York: The Advertising Bureau, 1900.

This volume is a complete and accurate record of the advertising of the United States for the year 1900. It contains a full and complete record of the advertising of the United States for the year 1900.

ADVERTISING IN THE UNITED STATES, 1900. By J. W. B. WILSON. New York: The Advertising Bureau, 1900.

This volume is a complete and accurate record of the advertising of the United States for the year 1900. It contains a full and complete record of the advertising of the United States for the year 1900.

OBJECTS,  
ADVANTAGES, AND PLEASURES  
OF  
SCIENCE.





## INTRODUCTION.

IN order fully to understand the advantages and the pleasures which are derived from an acquaintance with any Science, it is necessary to become acquainted with that Science ; and it would therefore be impossible to convey a complete knowledge of the benefits conferred by a study of the various Sciences which have hitherto been cultivated by philosophers, without teaching all the branches of them. But a very distinct idea may be given of those benefits, by explaining the nature and objects of the different Sciences : it may be shown, by examples, how much use and gratification there is in learning a part of any one branch of knowledge ; and it may thence be inferred, how great reason there is to learn the whole.

It may easily be demonstrated, that there is an advantage in learning, both for the usefulness and the pleasure of it. There is something positively agreeable to all men, to all at least whose nature is not most grovelling and base, in gaining knowledge for its own sake. When you see anything for the

first time, you at once derive some gratification from the sight being new ; your attention is awakened, and you desire to know more about it. If it is a piece of workmanship, as an instrument, or a machine of any kind, you wish to know how it is made ; how it works ; and what use it is of. If it is an animal, you desire to know where it comes from ; how it lives ; what are its dispositions, and, generally, its nature and habits. You feel this desire, too, without at all considering that the machine or the animal may ever be of the least use to yourself practically ; for, in all probability, you may never see them again. But you have a curiosity to learn all about them, because they are new and unknown. You accordingly make inquiries ; you feel a gratification in getting answers to your questions, that is, in receiving information, and in knowing more,—in being better informed than you were before. If you happen again to see the same instrument or animal, you find it agreeable to recollect having seen it formerly, and to think that you know something about it. If you see another instrument or animal, in some respects like, but differing in other particulars, you find it pleasing to compare them together, and to note in what they agree, and in what they differ. Now, all this kind of gratification is of a pure and disinterested nature, and has no reference to any of the common purposes of life ; yet it is a pleasure—an enjoy-

ment. You are nothing the richer for it ; you do not gratify your palate or any other bodily appetite ; and yet it is so pleasing, that you would give something out of your pocket to obtain it, and would forego some bodily enjoyment for its sake. The pleasure derived from Science is exactly of the like nature, or, rather, it is the very same. For what has just been spoken of is, in fact, Science, which in its most comprehensive sense only means *Knowledge*, and in its ordinary sense means *Knowledge reduced to a System* ; that is, arranged in a regular order, so as to be conveniently taught, easily remembered, and readily applied.

The practical uses of any science or branch of knowledge are undoubtedly of the highest importance ; and there is hardly any man who may not gain some positive advantage in his worldly wealth and comforts, by increasing his stock of information. But there is also a pleasure in seeing the uses to which knowledge may be applied, wholly independent of the share we ourselves may have in those practical benefits. It is pleasing to examine the nature of a new instrument, or the habits of an unknown animal, without considering whether or not they may ever be of use to ourselves or to any body. It is another gratification to extend our inquiries, and find that the instrument or animal is useful to man, even although we have no chance of ever benefiting by the information : as, to find that

the natives of some distant country employ the animal in travelling;—nay, though we have no desire of benefiting by the knowledge; as for example, to find that the instrument is useful in performing some dangerous surgical operation. There is mere gratification of curiosity; the knowing more to-day than we knew yesterday; the understanding clearly what before seemed obscure and puzzling; the contemplation of general truths, and the comparing together of different things,—is an agreeable occupation of the mind; and, beside the present enjoyment, elevates the faculties above low pursuits, purifies and refines the passions, and helps our reason to assuage their violence.

It is very true, that the fundamental lessons of philosophy may to many, at first sight, wear a forbidding aspect, because to comprehend them requires an effort of the mind somewhat, though certainly not much, greater than is wanted for understanding more ordinary matters; and the most important branches of philosophy, those which are of the most general application, are for that very reason the less easily followed, and the less entertaining when apprehended, presenting as they do few particulars or individual objects to the mind. In discoursing of them, moreover, no figures will be at present used to assist the imagination; the appeal is made to reason, without help from the senses. But be not, therefore, prejudiced against the doc-



trine, that the pleasure of learning the truths which philosophy unfolds is truly above all price. Lend but a patient attention to the principles explained, and giving us credit for stating nothing which has not some practical use belonging to it, or some important doctrine connected with it, you will soon perceive the value of the lessons you are learning, and begin to interest yourselves in comprehending and recollecting them; you will find that you have actually learnt something of science, while merely engaged in seeing what its end and purpose is; you will be enabled to calculate for yourselves, how far it is worth the trouble of acquiring, by examining samples of it; you will, as it were, taste a little, to try whether or not you relish it, and ought to seek after more; you will enable yourselves to go on, and enlarge your stock of it; and after having first mastered a very little, you will proceed so far as to look back with wonder at the distance you have reached beyond your earliest acquirements.

The Sciences may be divided into three great classes: those which relate to *Number and Quantity*—those which relate to *Matter*—and those which relate to *Mind*. The first are called the *Mathematics*, and teach the property of numbers and of figures; the second are called *Natural Philosophy*, and teach the properties of the various bodies which we are acquainted with by means of our senses; the third are called *Intellectual* or

*Moral Philosophy*, and teach the nature of the mind, of the existence of which we have the most perfect evidence in our own reflections; or, in other words, they teach the moral nature of man, both as an individual and as a member of society. Connected with all the sciences, and subservient to them, though not one of their number, is *History*, or the record of facts relating to all kinds of knowledge.

# I. MATHEMATICAL SCIENCE.

THE two great branches of the *Mathematics*, or the two mathematical sciences, are *Arithmetic*, the science of number, from the Greek word signifying *number*, and *Geometry*, the science of figure, from the Greek words signifying *measure of the earth*,—land-measuring having first turned men's attention to it.

When we say that 2 and 2 make 4, we state an arithmetical proposition, very simple indeed, but connected with many others of a more difficult and complicated kind. Thus, it is another proposition, somewhat less simple, but still very obvious, that 5 multiplied by 10, and divided by 2 is equal to, or makes the same number with, 100 divided by 4—both results being equal to 25. So, to find how many farthings there are in 1000*l.*, and how many

minutes in a year, are questions of arithmetic which we learn to work by being taught the principles of the science one after another, or, as they are commonly called, the *rules* of addition, subtraction, multiplication, and division. Arithmetic may be said to be the most simple, though among the most useful of the sciences; but it teaches only the properties of particular and known numbers, and it only enables us to add, subtract, multiply, and divide those numbers. But suppose we wish to add, subtract, multiply, or divide numbers which we have not yet ascertained, and in all respects to deal with them as if they were known, for the purpose of arriving at certain conclusions respecting them, and, among other things, of discovering what they are; or, suppose we would examine properties belonging to all numbers; this must be performed by a peculiar kind of arithmetic, called *Universal arithmetic*, or *Algebra*.\* The common arithmetic, you will presently perceive, carries the seeds of this most important science in its bosom. Thus, suppose we inquire what is the number which multiplied by 5 makes 10? This is found if we divide 10 by 5,—it is 2: but suppose that, before finding this number 2, and before knowing what it is, we would add it, whatever it may turn

\* Algebra, from the Arabic words signifying the *reduction of fractions*; the Arabs having brought the knowledge of it into Europe.

out, to some other number ; this can only be done by putting some mark, such as a letter of the alphabet, to stand for the unknown number, and adding that letter as if it were a known number. Thus, suppose we want to find two numbers which, added together, make 9, and, multiplied by one another, make 20. There are many which, added together, make 9 ; as 1 and 8 ; 2 and 7 ; 3 and 6 ; and so on. We have, therefore, occasion to use the second condition, that multiplied by one another they should make 20, and to work upon this condition before we have discovered the particular numbers. We must, therefore, suppose the numbers to be found, and put letters for them, and by reasoning upon those letters, according to both the two conditions of adding and multiplying, we find what they must each of them be in figures, in order to fulfil or answer the conditions. Algebra teaches the rules for conducting this reasoning, and obtaining this result successfully ; and by means of it we are enabled to find out numbers which are unknown, and of which we only know that they stand in certain relations to known numbers, or to one another. The instance now taken is an easy one ; and you could, by considering the question a little, answer it readily enough ; that is, by trying different numbers, and seeing which suited the conditions ; for you plainly see that 5 and 4 are the two numbers sought ; but you



see this by no certain or general rule applicable to all cases, and therefore you could never work more difficult questions in the same way; and even questions of a moderate degree of difficulty would take an endless number of trials or guesses to answer. Thus a shepherd sold his flock for 80*l.*; and if he had sold four sheep more for the same money, he would have received one pound less for each sheep. To find out from this, how many the flock consisted of, is a very easy question in algebra, but would require a vast many guesses, and a long time to hit upon by common arithmetic:\*. And questions infinitely more difficult can easily be solved by the rules of algebra. In like manner, by arithmetic you can tell the properties of particular numbers; as, for instance, that the number 348 is divided by 3 exactly, so as to leave nothing over: but algebra teaches us that it is only one of an infinite variety of numbers, all divisible by 3, and any one of which you can tell the moment you see it; for they all have the remarkable property, that if you add together the figures they consist of, the sum total is divisible by 3. You can easily perceive this in any one case, as in the number mentioned, for 3 added to 4 and that to 8 make 15, which is plainly divisible by 3; and if you divide 348 by 3, you find the quotient to be 116, with nothing over. But this does not at all prove that

\* It is 16.

any other number, the sum of whose figures is divisible by 3, will itself also be found divisible by 3, as 741; for you must actually perform the division here, and in every other case, before you can know that it leaves nothing over. Algebra, on the contrary, both enables you to discover such general properties, and to prove them in all their generality.\*

By means of this science, and its various applications, the most extraordinary calculations may be performed. We shall give, as an example, the method of *Logarithms*, which proceeds upon this principle. Take a set of numbers going on by equal differences; that is to say, the third being as much greater than the second, as the second is greater than the first, and the common difference being the number you begin with; thus, 1, 2, 3, 4, 5, 6, and so on, in which the common difference is 1: then take another set of numbers,

\* Another class of numbers divisible by 3 is discovered in like manner by algebra. Every number of 3 places, the figures (or digits) composing which are in arithmetical progression, (or rise above each other by equal differences,) is divisible by 3: as 123, 789, 357, 159, and so on. The same is true of numbers of any amount of places, provided they are composed of 3, 6, 9, &c., numbers rising above each other by equal differences, as 289, 299, 309, or 148, 214, 280, or 307142085345648276198756, which number of 24 places is divisible by 3, being composed of 6 numbers in a series whose common difference is 1137. This property, too, is only a particular case of a much more general one.

such that each is equal to twice or three times the one before it, or any number of times the one before it, but the common multiplier being the number you begin with : thus, 2, 4, 8, 16, 32, 64, 128 ; write this second set of numbers under the first, or side by side, so that the numbers shall stand opposite to one another, thus,

1	2	3	4	5	6	7
2	4	8	16	32	64	128

you will find, that if you add together any two of the upper or first set, and go to the number opposite their sum, in the lower or second set, you will have in this last set the number arising from multiplying together the numbers of the lower set corresponding or opposite to the numbers added together. Thus, add 2 to 4, you have 6 in the upper set, opposite to which in the lower set is 64, and multiplying the numbers 4 and 16 opposite to 2 and 4, the product is 64. In like manner, if you subtract one of the upper numbers from another, and opposite to their difference in the upper line, you look to the lower number, it is the quotient found from dividing one of the lower numbers by the other opposite the subtracted ones. Thus, take 4 from 6 and 2 remains, opposite to which you have in the lower line 4 ; and if you divide 64, the number opposite to 6, by 16, the number opposite to 4, the quotient is 4. The upper set are called the *logarithms*, of the lower

set, which are called *natural numbers*; and tables may, with a little trouble, be constructed, giving the logarithms of all numbers from 1 to 10,000 and more: so that, instead of multiplying or dividing one number by another, you have only to add or subtract their logarithms, and then you at once find the product or the quotient in the tables. These are made applicable to numbers far higher than any actually in them, by a very simple process: so that you may at once perceive the prodigious saving of time and labour which is thus made. If you had, for instance, to multiply 7,543,283 by itself, and that product again by the original number, you would have to multiply a number of 7 places of figures by an equally large number, and then a number of 14 places of figures by one of 7 places, till at last you had a product of 21 places of figures—a very tedious operation; but, working by logarithms, you would only have to take three times the logarithm of the original number, and that gives the logarithm of the last product of 21 places of figures, without any further multiplication. So much for the time and trouble saved, which is still greater in questions of division; but by means of logarithms many questions can be worked, and of the most important kind, which no time or labour would otherwise enable us to resolve.

*Geometry* teaches the properties of figure, or particular portions of space, and distances of points.



from each other. Thus, when you see a triangle, or three-sided figure, one of whose sides is perpendicular to another side, you find, by means of geometrical reasoning respecting this kind of triangle, that if squares be drawn on its three sides, the large square upon the slanting side opposite the two perpendiculars, is exactly equal to the smaller squares upon the perpendiculars, taken together; and this is absolutely true, whatever be the size of the triangle, or the proportions of its sides to each other. Therefore, you can always find the length of any one of the three sides by knowing the lengths of the other two. Suppose one perpendicular side to be 3 feet long, the other 4, and you want to know the length of the third side opposite to the perpendicular; you have only to find a number such, that if, multiplied by itself, it shall be equal to 3 times 3, together with 4 times 4, that is 25.\* (This number is 5.)

Now only observe the great advantage of knowing this property of the triangle, or of perpendicular lines. If you want to measure a line passing over ground which you cannot reach—to know,

\* It is a property of numbers, that every number whatever, whose last place is either 5 or 0, is, when multiplied into itself, equal to two others which are square numbers, and divisible by 3 and 4 respectively:—thus,  $45 \times 45 = 2025 = 729 + 1296$ , the squares of 27 and 36; and  $60 \times 60 = 3600 = 1296 + 2304$ , the squares of 36 and 48.

for instance, the length of one side, covered with water, of a field, or the distance of one point on a lake or bay from another point on the opposite side—you can easily find it by measuring two lines perpendicular to one another on the dry land, and running through the two points; for the line wished to be measured, and which runs through the water, is the third side of a perpendicular-sided triangle, the other two sides of which are ascertained. But there are other properties of triangles, which enable us to know the length of two sides of any triangle, whether it has perpendicular sides or not, by measuring one side, and also measuring the inclinations of the other two sides to this side, or what is called the two *angles* made by those sides with the measured side. Therefore you can easily find the perpendicular line drawn, or supposed to be drawn, from the top of a mountain through it to the bottom, that is, the height of the mountain; for you can measure a line on level ground, and also the inclination of two lines, supposing them drawn in the air, and reaching from the two ends of the measured line to the mountain's top; and having thus found the length of the one of those lines next the mountain, and its inclination to the ground, you can at once find the perpendicular, though you cannot possibly get near it. In the same way, by measuring lines and angles on the ground, and near, you can find the length of

lines at a great distance, and which you cannot approach: for instance, the length and breadth of a field on the opposite side of a lake or sea; the distance of two islands; or the space between the tops of two mountains.

Again, there are *curve-lined* figures as well as straight, and geometry teaches the properties of these also. The best known of all the curves is the *circle*, or a figure made by drawing a string round one end which is fixed, and marking where its other end traces, so that every part of the circle is equally distant from the fixed point or centre. From this fundamental property, an infinite variety of others follow by steps of reasoning more or less numerous, but all necessarily arising one out of another. To give an instance; it is proved by geometrical reasoning, that if from the two ends of any diameter of the circle you draw two lines to meet in any one point of the circle whatever, those lines are perpendicular to each other.

Another property, and a most useful one, is, that the sizes, or areas, of all circles whatever, from the greatest to the smallest, from the sun to a watch-dialplate, are in exact proportion to the squares of their distances from the centre; that is, the squares of the strings they are drawn with: so that if you draw a circle with a string 5 feet long, and another with a string 10 feet long, the large circle is four times the size of the small one, as far

as the space or area inclosed is concerned; the square of 10 or 100 being four times the square of 5 or 25. But it is also true, that the lengths of the circumferences themselves, the number of feet over which the ends of the strings move, are in proportion to the lengths of the strings; so that the curve of the large circle is only twice the length of the curve of the lesser.

But the circle is only one of an infinite variety of curves, all having a regular formation and fixed properties. The *oval* or *ellipse* is, perhaps, next to the circle, the most familiar to us, although we more frequently see another curve, the line formed by the motion of bodies thrown forward. When you drop a stone, or throw it straight up, it goes in a straight line; when you throw it forward, it goes in a curve line till it reaches the ground; as you see by the figure in which water runs when forced out of a pump, or from a fire-pipe, or from the spout of a kettle or teapot. The line it moves in is called a *parabola*; every point of which bears a certain fixed relation to a certain point within it, as the circle does to its centre. Geometry teaches various properties of this curve: for example, if the direction in which the stone is thrown, or the bullet fired, or the water spouted, be half the perpendicular to the ground, that is, half way between being level with the ground and being upright, the curve will come to the ground at a



greater distance than if any other direction whatever were given, with the same force. So that, to make the gun carry farthest, or the fire-pipe play to the greatest distance, they must be pointed, not, as you might suppose, level or point blank, but about half way between that direction and the perpendicular. If the air did not resist, and so somewhat disturb the calculation, the direction to give the longest range ought to be exactly half perpendicular.

The *oval*, or *ellipse*, is drawn by taking a string of any certain length, and fixing, not one end as in drawing the circle, but both ends to different points, and then carrying a point round inside the string, always keeping it stretched as far as possible. It is plain, that this figure is as regularly drawn as the circle, though it is very different from it; and you perceive that every point of its curve must be so placed, that the straight lines drawn from it to the two points where the string was fixed, are, when added together, always the same; for they make together the length of the string.

Among various properties belonging to this curve, in relation to the straight lines drawn within it, is one which gives rise to the construction of the *trammels*, or elliptic compasses, used for making figures and ornaments of this form; and



also to the construction of lathes for turning oval frames, and the like.

If you wish at once to see these three curves, take a pointed sugar-loaf, and cut it any where clean through in a direction parallel to its base or bottom; the outline or edge of the loaf where it is cut will be a *circle*. If the cut is made so as to slant, and not be parallel to the base of the loaf, the outline is an *ellipse*, provided the cut goes quite through the sides of the loaf all round, or is in such a direction that it would pass through the sides of the loaf were they extended; but if it goes slanting and parallel to the line of the loaf's side, the outline is a *parabola*; and if you cut in any direction, not through the sides all round, but through the sides and base, and not parallel to the line of the side, being nearer the perpendicular, the outline will be another curve of which we have not yet spoken, but which is called an *hyperbola*. You will see another instance of it, if you take two plates of glass, and lay them on one another; then put their edge in water, holding them upright and pressing them together; the water, which, to make it more plain, you may colour with a few drops of ink or strong tea, rises to a certain height, and its outline is this curve; which, however much it may seem to differ in form from a circle or ellipse, is found by mathematicians to

resemble them very closely in many of its most remarkable properties.

These are the curve lines best known and most frequently discussed ; but there are an infinite number of others all related to straight lines and other curve lines by certain fixed rules : for example, the course which any point in the circumference of a circle, as a nail in the felly of a wheel rolling along, takes through the air, is a curve called the *cycloid*, which has many remarkable properties ; and, among others, this, that it is, of all lines possible, the one in which any body, not falling perpendicularly, will descend from one point to another the most quickly. Another curve often seen is that in which a rope or chain hangs when supported at both ends : it is called the *Catenary*, from the Latin for chain ; and in this form some arches are built. The form of a sail filled with wind is the same curve.

## II. DIFFERENCE BETWEEN MATHEMATICAL AND PHYSICAL TRUTHS.

You perceive, if you reflect a little, that the science which we have been considering, in both its branches, has nothing to do with matter ; that is to say, it does not at all depend upon the properties or even upon the existence of any bodies or sub-

stances whatever. The distance of one point or place from another is a straight line ; and whatever is proved to be true respecting this line, as, for instance, its proportion to other lines of the same kind, and its inclination towards them, what we call the *angles* it makes with them, would be equally true whether there were anything in those places, at those two points, or not. So if you find the number of yards in a square field, by measuring one side, 100 yards, and then, multiplying that by itself, which makes the whole area 10,000 square yards, this is equally true whatever the field is, whether corn, or grass, or rock, or water ; it is equally true if the solid part, the earth or water, be removed, for then it will be a field of air bounded by four walls or hedges ; but suppose the walls or hedges were removed, and a mark only left at each corner, still it would be true that the space inclosed or bounded by the lines supposed to be drawn between the four marks, was 10,000 square yards in size. But the marks need not be there ; you only want them while measuring one side : if they were gone, it would be equally true that the lines, supposed to be drawn from the places where the marks had been, inclose 10,000 square yards of air. But if there were no air, and consequently a mere void, or empty space, it would be equally true that this space is of the size you had found it to be by measuring the distance of one

point from another, of one of the space's corners or angles from another, and then multiplying that distance by itself. In the same way it would be true, that, if the space were circular, its size, compared with another circular space of half its diameter, would be four times larger : of one-third its diameter nine times larger, and of one-fourth sixteen times, and so on always in proportion to the squares of the diameters ; and that the length of the circumference, the number of feet or yards in the line round the surface, would be twice the length of a circle whose diameter was one half, thrice the circumference of one whose diameter was one-third, four times the circumference of one whose diameter was one-fourth, and so on, in the simple proportion of the diameters. Therefore, every property which is proved to belong to figures belongs to them without the smallest relation to bodies or matter of any kind, although we are accustomed only to see figures in connection with bodies ; but all those properties would be equally true if no such thing as matter or bodies existed ; and the same may be said of the properties of number, the other great branch of the mathematics. When we speak of twice two, and say it makes four, we affirm this without thinking of two horses, or two balls, or two trees ; but we assert it concerning two of any thing and every thing equally. Nay, this branch of mathematics may be said to apply still more ex-



tensively than even the other ; for it has no relation to space, which geometry has ; and, therefore, it is applicable to cases where figure and size are wholly out of the question. Thus you can speak of two dreams, or two ideas, or two minds, and can calculate respecting them just as you would respecting so many bodies ; and the properties you find belonging to numbers, will belong to those numbers when applied to things that have no outward or visible or perceivable existence, and cannot even be said to be in any particular place, just as much as the same numbers applied to actual bodies which may be seen and touched.

It is quite otherwise with the science which we are now going to consider, *Natural Philosophy*. This teaches the nature and properties of actually existing substances, their motions, their connections with each other, and their influence on one another. It is sometimes also called *Physics*, from the Greek word signifying *Nature*, though that word is more frequently, in common speech, confined to one particular branch of the science, that which treats of the bodily health.

We have mentioned one distinction between Mathematics and Natural Philosophy, that the former does not depend on the nature and existence of bodies, which the latter entirely does. Another distinction, and one closely connected with this, is, that the truths which Mathematics teach are



*necessarily* such,—they are truths of themselves, and wholly independent of facts and experiments,—they depend only upon reasoning; and it is utterly impossible they should be otherwise than true. This is the case with all the properties which we find belong to numbers and to figures—2 and 2 must of *necessity*, and through all time, and in every place, be equal to 4: those numbers must *necessarily* be always divisible by 3, without leaving any remainder over, which have the sums of the figures they consist of divisible by 3; and circles must *necessarily*, and for ever and ever, be to one another in the exact proportion of the squares of their diameters. It cannot be otherwise; we cannot conceive it in our minds to be otherwise. No man can in his own mind suppose to himself that 2 and 2 should ever be more or less than 4; it would be an utter impossibility—a contradiction in the very ideas; and if stated in words, those words would have no sense. The other properties of number, though not so plain at first sight as this, are proved to be true by reasoning, every one step of which follows from the step immediately before, as a matter of course, and so clearly and unavoidably, that it cannot be supposed, or even imagined, to be otherwise; the mind has no means of fancying how it could be otherwise: the final conclusion, from all the steps of the reasoning or demonstration, as it is called, follows in the same way from the

last of the steps, and is therefore just as evidently and necessarily true as the first step, which is always something self-evident; for instance, that 2 and 2 make 4, or that the whole is greater than any one of its parts, but equal to all its parts put together. It is through this kind of reasoning, step by step, from the most plain and evident things, that we arrive at the knowledge of other things which seem at first not true, or at least not generally true; but when we do arrive at them, we perceive that they are just as true, and for the same reasons, as the first and most obvious matters; that their truth is absolute and necessary, and that it would be as absurd and self-contradictory to suppose they ever could, under any circumstances, be not true, as to suppose that 2 added to 2 could ever make 3, or 5, or 100, or anything but 4; or, which is the same thing, that 4 should ever be equal to 3, or 5, or 100, or anything but 4. To find out these reasonings, to pursue them to their consequences, and thereby to discover the truths which are not immediately evident, is what science teaches us; but when the truth is once discovered, it is as certain and plain by the reasoning, as the first truths themselves from which all the reasoning takes its rise, on which it all depends, and which require no proof, because they are self-evident at once, and must be assented to the instant they are understood.

But it is quite different with the truths which Natural Philosophy teaches. All these depend upon matter of fact ; and that is learnt by observation and experiment, and never could be discovered by reasoning at all. If a man were shut up in a room with pen, ink, and paper, he might by thinking discover any of the truths in arithmetic, algebra, or geometry ; it is possible at least ; there would be nothing absolutely impossible in his discovering all that is now known of these sciences ; and if his memory were as good as we are supposing his judgment and conception to be, he might discover it all without pen, ink, and paper, and in a dark room. But we cannot discover a single one of the fundamental properties of matter without observing what goes on around us, and trying experiments upon the nature and motion of bodies. Thus, the man whom we have supposed shut up, could not possibly find out beyond one or two of the very first properties of matter, and those only in a very few cases ; so that he could not tell if these were general properties of all matter or not. He could tell that the objects he touched in the dark were hard and resisted his touch ; that they were extended and were solid : that is, that they had three dimensions, length, breadth, and thickness. He might guess that other things existed besides those he felt, and that those other things resembled what he felt in these properties ; but he could know

nothing for certain, and could not even conjecture much beyond this very limited number of qualities. He must remain utterly ignorant of what really exists in nature, and of what properties matter in general has. These properties, therefore, we learn by experience; they are such as we know bodies to have; they happen to have them—they are so formed by Divine Providence as to have them—but they might have been otherwise formed; the great Author of Nature might have thought fit to make all bodies different in every respect. We see that a stone dropped from our hand falls to the ground; this is a fact which we can only know by experience; before observing it, we could not have guessed it, and it is quite *conceivable* that it should be otherwise: for instance, that when we remove our hand from the body it should stand still in the air; or fly upward, or go forward, or backward, or sideways; there is nothing at all absurd, contradictory, or inconceivable in any of these suppositions; there is nothing impossible in any of them, as there would be in supposing the stone equal to half of itself, or double of itself; or both falling down and rising upwards at once; or going to the right and to the left at one and the same time. Our only reason for not at once thinking it quite conceivable that the stone should stand still in the air, or fly upwards, is that we have never seen it do so, and have become accustomed to see



it do otherwise. But for that, we should at once think it as natural that the stone should fly upwards or stand still, as that it should fall down. But no degree of reflection for any length of time could accustom us to think 2 and 2 equal to anything but 4, or to believe the whole of any thing equal to a part of itself.

After we have once, by observation or experiment, ascertained certain things to exist in fact, we may then reason upon them by means of the mathematics ; that is, we may apply mathematics to our experimental philosophy, and then such reasoning becomes absolutely certain, taking the fundamental facts for granted. Thus, if we find that a stone falls in one direction when dropped, and we further observe the peculiar way in which it falls, that is, quicker and quicker every instant till it reaches the ground, we learn the rule or the proportion by which the quickness goes on increasing ; and we further find, that if the same stone is pushed forward on a table, it moves in the direction of the push, till it is either stopped by something, or comes to a pause by rubbing against the table and being hindered by the air. These are facts which we learn by observing and trying, and they might all have been different if matter and motion had been otherwise constituted ; but supposing them to be as they are, and as we find them, we can, by reasoning mathematically from them, find



out many most curious and important truths depending upon those facts, and depending upon them not accidentally, but of necessity. For example, we can find in what course the stone will move, if, instead of being dropped to the ground, it is thrown forward: it will go in the curve already mentioned, the parabola, somewhat altered by the resistance of the air, and it will run through that curve in a peculiar way, so that there will always be a certain proportion between the time it takes and the space it moves through, and the time it would have taken, and the space it would have moved through, had it dropped from the hand in a straight line to the ground. So we can prove, in like manner, what we before stated of the relation between the distance at which it will come to the ground, and the direction it is thrown in; the distance being greatest of all when the direction is half way between the level or horizontal and the upright or perpendicular. These are mathematical truths, derived by mathematical reasoning upon physical grounds; that is, upon matter of fact found to exist by actual observation and experiment. The result, therefore, is necessarily true, and proved to be so by reasoning only, provided we have once ascertained the facts; but taken altogether, the result depends partly on the facts learned by experiment or experience, partly on the reasoning from these facts. Thus it is found to be true by

reasoning, and necessarily true, that *if* the stone falls in a certain way when unsupported, it must, when thrown forward, go in the curve called a parabola, provided there be no air to resist: this is a necessary or mathematical truth, and it cannot possibly be otherwise. But when we state the matter without any supposition,—without any “*if*,”—and say, a stone thrown forward goes in a curve called a parabola, we state a truth, partly fact, and partly drawn from reasoning on the fact; and it might be otherwise if the nature of things were different. It is called a proposition or truth in Natural Philosophy; and as it is discovered and proved by mathematical reasoning upon facts in nature, it is sometimes called a proposition or truth in the *Mixed Mathematics*, so named in contradistinction to the *Pure Mathematics*, which are employed in reasoning upon figures and numbers. The man in the dark room could never discover this truth unless he had been first informed, by those who had observed the fact, in what way the stone falls when unsupported, and moves along the table when pushed. These things he never could have found out by reasoning: they are facts, and he could only reason from them after learning them by his own experience, or taking them on the credit of other people’s experience. But having once so learnt them, he could discover by reasoning merely, and with as much certainty as if he lived

in daylight, and saw and felt the moving body, that the motion is a parabola, and governed by certain rules. As experiment and observation are the great sources of our knowledge of Nature, and as the judicious and careful making of experiments is the only way by which her secrets can be known, Natural and Experimental Philosophy mean one and the same thing ; mathematical reasoning being applied to certain branches of it, particularly those which relate to motion and pressure.

### III. NATURAL OR EXPERIMENTAL SCIENCE.

NATURAL PHILOSOPHY, in its most extensive sense, has for its province the investigation of the laws of matter ; that is, the properties and the motions of matter ; and it may be divided into two great branches. The first and most important (which is sometimes, on that account, called *Natural Philosophy* by way of distinction, but more properly *Mechanical Philosophy*) investigates the sensible motions of bodies. The second investigates the constitution and qualities of all bodies, and has various names, according to its different objects. It is called *Chemistry*, if it teaches the properties of bodies with respect to heat, mixture with one another, weight, taste, appearance, and so forth ; *Anatomy* and *Animal*

*Physiology*, (from the Greek word signifying *to speak of the nature* of any thing,) if it teaches the structure and functions of living bodies, especially the human; for, when it shows those of other animals, we term it *Comparative Anatomy*; *Medicine*, if it teaches the nature of diseases, and the means of preventing them and of restoring health; *Zoology*, (from the Greek words signifying *to speak of animals*,) if it teaches the arrangement or classification and the habits of the different lower animals; *Botany*, (from the Greek word for *herbage*,) including *Vegetable Physiology*, if it teaches the arrangement or classification, the structure and habits of plants; *Mineralogy*, including *Geology*, (from the Greek words meaning *to speak of the earth*,) if it teaches the arrangement of minerals, the structure of the masses in which they are found, and of the earth composed of those masses. The term *Natural History* is given to the three last branches taken together, but chiefly as far as they teach the classification of different things, or the observation of the resemblances and differences of the various animals, plants, and inanimate and ungrowing substances in nature.

But here we may make two general observations. The *first* is, that every such distribution of the sciences is necessarily imperfect; for one runs unavoidably into another. Thus, Chemistry shows the qualities of plants with relation to other sub-



stances, and to each other ; and Botany does not overlook those same qualities, though its chief object be arrangement. So Mineralogy, though principally conversant with classifying metals and earths, yet regards also their qualities in respect of heat and mixture. So, too, Zoology, besides arranging animals, describes their structures, like Comparative Anatomy. In truth, all arrangement and classifying depends upon noting the things in which the objects agree and differ ; and among those things, in which animals, plants, and minerals agree, or differ, must be considered the anatomical qualities of the one and the chemical qualities of the other. From hence, in a great measure, follows the *second* observation, namely, that the sciences mutually assist each other. We have seen how Arithmetic and Algebra aid Geometry, and how both the purely Mathematical Sciences aid Mechanical Philosophy. Mechanical Philosophy, in like manner, assists, though, in the present state of our knowledge, not very considerably, both Chemistry and Anatomy, especially the latter ; and Chemistry very greatly assists both Physiology, Medicine, and all the branches of Natural History.

The first great head, then, of Natural Science, is Mechanical Philosophy ; and it consists of various subdivisions, each forming a science of great importance. The most essential of these,



and which is indeed fundamental, and applicable to all the rest, is called *Dynamics*, from the Greek word signifying *power* or *force*, and it teaches the laws of motion in all its varieties. The case of the stone thrown forward, which we have already mentioned more than once, is an example. Another, of a more general nature, but more difficult to trace, far more important in its consequences, and of which, indeed, the former is only one particular case, relates to the motions of all bodies, which are attracted (or influenced, or drawn) by any power towards a certain point, while they are, at the same time, driven forward, by some push given to them at first, and forcing them onwards, at the same time that they are drawn towards the point. The line in which a body moves while so drawn and so driven, depends upon the force it is pushed with, the direction it is pushed in, and the kind of power that draws it towards the point; but at present, we are chiefly to regard the latter circumstance, the attraction towards the point. If this attraction be uniform, that is, the same at all distances from the point, the body will move in a circle, if one direction be given to the forward push. The case with which we are best acquainted is when the force decreases as the squares of the distances, from the centre or point of attraction, increase; that is, when the force is four times less at twice the distance, nine times less at thrice the

distance, sixteen times less at four times the distance, and so on. A force of this kind acting on the body, will make it move in an oval, a parabola, or an hyperbola, according to the amount or direction of the impulse, or forward push, originally given; and there is one proportion of that force, which, if directed perpendicularly to the line in which the central force draws the body, will make it move round in a circle, as if it were a stone tied to a string and whirled round the hand. The most usual proportions in nature, are those which determine bodies to move in an oval or ellipse, the curve described by means of a cord fixed at both ends, in the way already explained. In this case, the point of attraction, the point towards which the body is drawn, will be nearer one end of the ellipse than the other, and the time the body will take to go round, compared with the time any other body would take, moving at a different distance from the same point of attraction, but drawn towards that point with a force which bears the same proportion to the distance, will bear a certain proportion, discovered by mathematicians, to the average distances of the two bodies from the point of common attraction. If you multiply the numbers expressing the times of going round, each by itself, the products will be to one another in the proportion of the average distances multiplied each by itself, and that product again by the dis-

tance. Thus, if one body take two hours, and is five yards distant, the other, being ten yards off, will take something less than five hours and forty minutes.\*

Now, this is one of the most important truths in the whole compass of science; for it does so happen, that the force with which bodies fall towards the earth, or what is called their *gravity*, the power that draws or attracts them towards the earth, varies with the distance from the Earth's centre, exactly in the proportion of the squares, lessening as the distance increases: at two diameters from the Earth's centre, it is four times less than at one; at three diameters, nine times less; and so forth. It goes on lessening, but never is destroyed, even at the greatest distances to which we can reach by our observations, and there can be no doubt of its extending indefinitely beyond. But, by astronomical observations made upon the motion of the heavenly bodies, upon that of the Moon for instance, it is proved that her movement is slower and quicker at different parts of her course, in the same manner as a body's motion on the earth would be slower and quicker, according to its distance from the point it was drawn towards,

\* This is expressed mathematically by saying, that the squares of the times are as the cubes of the distances. Mathematical language is not only the simplest and most easily understood of any, but the shortest also.

provided it was drawn by a force acting in the proportion to the squares of the distance, which we have frequently mentioned; and the proportion of the time to the distance is also observed to agree with the rule above referred to. Therefore, she is shown to be attracted towards the Earth by a force that varies according to the same proportion in which gravity varies; and she must consequently move in an ellipse round the Earth, which is placed in a point nearer the one end than the other of that curve. In like manner, it is shown that the Earth moves round the Sun in the same curve line, and is drawn towards the sun by a similar force; and that all the other planets in their courses, at various distances, follow the same rule, moving in ellipses, and drawn towards the Sun by the same kind of power. Three of them have moons like the Earth, only more numerous, for Jupiter has four, Saturn seven, and Herschel six, so very distant, that we cannot see them without the help of glasses; but all those moons move round their principal planets, as ours does round the Earth, in ovals or ellipses; while the planets, with their moons, move in their ovals round the Sun, like our own Earth with its moon.

But this power, which draws them all towards the sun, and regulates their path and their motion round him, and which draws the moons towards the principal planets, and regulates their motion



and path round those planets, is the same with the gravity by which bodies fall towards the earth, being attracted by it. Therefore, the whole of the heavenly bodies are kept in their places, and wheel round the sun, by the same influence or power that makes a stone fall to the ground.

It is usual to call the sun, and the planets which with their moons move round him (eleven in number, including the four lately discovered, and the one discovered by Herschel), the *Solar System*, because they are a class of the heavenly bodies far apart from the innumerable fixed stars, and so near each other as to exert a perceptible influence on one another, and thus to be connected together.

The *Comets* belong to the same system, according to this manner of viewing the subject. They are bodies which move in elliptical paths, but far longer and narrower than the curves in which the earth and the other planets and their moons roll. Our curves are not much less round than circles; the paths of the comets are long and narrow, so as, in many places, to be more nearly straight lines than circles. They differ from the planets and their moons in another respect; they do not depend on the sun for the light they give, as our moon plainly does, being dark when the earth comes between her and the sun; and as the other planets do, those of them that are nearer the sun than we

are, being dark when they come between us and him, appearing to pass across his surface. But the comets give light always of themselves, being apparently vast bodies heated red-hot by coming in their course far nearer the sun than the nearest of the planets ever do. Their motion, when near the sun, is much more rapid than that of the planets; they both approach him much nearer, retreat from him to much greater distances, and take much longer time in going round him than any of the planets do. Yet even these comets are subject to the same great law of gravitation which regulates the motions of the planets. Their year, the time they take to revolve, is in some cases 75, in others 135, in others 300 of our years; their distance is a hundred times our distance when farthest off, and not a hundred and sixtieth of our distance when nearest the sun; their swiftest motion is above twelve times swifter than ours, although ours is a hundred and forty times swifter than a cannon ball's; yet their path is a curve of the same kind with ours, though longer and flatter, differing in its formation only as one oval differs from another by the string you draw it with having the ends fixed at two points more distant from each other: consequently the sun, being in one of those points, is much nearer the end of the path the comet moves in, than he is near the end of our path. Their motion, too, follows the same rule, being

swifter the nearer the sun: the attraction of the sun for them varies according to the squares of the distances, being four times less at twice the distance, nine times less at thrice, and so on; and the proportion between the times of revolving and the distances is exactly the same, in the case of those remote bodies, as in that of the moon and the earth. One law prevails over all, and regulates their motions as well as our own; it is the gravity of the comets towards the sun, and they, like our own earth and moon, wheel round him in boundless space, drawn by the same force, acting by the same rule, which makes a stone fall when dropped from the hand.

The more full and accurate our observations are upon those heavenly bodies, the better we find all their motions agreeing with this great doctrine; although, no doubt, many things are to be taken into the account besides the force that draws them to the different centres. Thus, while the moon is drawn by the earth, and the earth by the sun, the moon is also drawn directly by the sun; and while Jupiter is drawn by the sun, so are his moons; and both Jupiter and his moons are drawn by Saturn: nay, as this power of gravitation is quite universal, and as no body can attract or draw another without being itself drawn by that other, the earth is drawn by the moon, while the moon is drawn by the earth; and the sun is attracted by

the planets which he draws towards himself. These mutual attractions give rise to many deviations from the simple line of the ellipse, and produce many irregularities in the simple calculation of the times and motions of the bodies that compose the system of the universe. But the extraordinary powers of investigation applied to the subject by the modern improvements in mathematics have enabled us at length to reduce even the greatest of the irregularities to order and system, and to unfold one of the most wonderful truths in all sciences, namely, that by certain necessary consequence of the simple fact upon which the whole fabric rests, the proportion of the attractive force to the distances at which it operates,—all the irregularities which at first seemed to disturb the order of the system, and to make the appearances depart from the doctrine, are themselves subject to a certain fixed rule, and can never go beyond a particular point, but must begin to lessen when they have slowly reached that point, and must then lessen until they reach another point, when they begin again to increase; and so on, for ever. Nay, so perfect is the arrangement of the whole system, and so accurately does it depend upon mathematical principles, that irregularities, or rather apparent deviations, have been discovered by mathematical reasoning before astronomers had observed them, and then their existence has been



ascertained by observation, and found to agree precisely with the results of calculation.\* Thus, the planets move in ovals, from gravity, the power that attracts them towards the sun, combined with the original impulse they received forwards; and the disturbing forces are continually varying the course of the curves or ovals, making them bulge out in the middle, as it were, on the sides, though in a very small proportion to the whole length of the ellipse. The oval thus bulging, its breadth increases by a very small quantity yearly and daily; and after a certain large number of years, the bulging becomes as great as it ever can be: then the alteration takes a contrary direction, and the curve gradually flattens as it had bulged; till, in the same number of years which it took to bulge,

\* The application of mathematics to chemistry has already produced a great change in that science, and is calculated to produce still greater improvements. It may be almost certainly reckoned upon as the source of new discoveries, made by induction after the mathematical reasoning has given the suggestion. The learned reader will perceive that we allude to the beautiful doctrine of *Definite* or *Multiple Proportions*. To take an example; the probability of an oxide of arsenic being discovered is impressed upon us, by the composition of arsenious and arsenic acids, in which the oxygen is as 2 to 3; and therefore we may expect to find a compound of the same base, with the oxygen as unity. The extraordinary action of chlorine and its compounds on light leads us to expect some further discovery respecting its composition, perhaps respecting the matter of light.

it becomes as flat as it ever can be, and then it begins to bulge again, and so on for ever. And so, too, of every other disturbance and irregularity in the system: what at first appears to be some departure from the rule, when more fully examined, turns out to be only a consequence of it, or the result of a more general arrangement springing from the principle of gravitation; an arrangement of which the rule itself, and the apparent or supposed exception, both form parts.

The power of gravitation, which thus regulates the whole system of the universe, is found to rule each member or branch of it separately. Thus, it is demonstrated that the tides of the ocean are caused by the gravitation which attracts the water towards the sun and moon; and the figure both of our earth and of such of the other bodies as have a spinning motion round their axis, is determined by gravitation combined with that motion: they are all flattened towards the ends of the axis they spin upon, and bulge out towards the middle.

The great discoverer of the principle on which all these truths rest, Sir Isaac Newton, certainly, by far the most extraordinary man that ever lived, concluded by reasoning upon the nature of motion and matter, that this flattening must take place in our globe; every one before his time had believed the earth to be a perfect sphere or globe, chiefly from observing the round shadow which it casts on

the moon in eclipses ; and it was many years after his death that the accuracy of his opinion was proved by measurements on the earth's surface, and by the different weight and attraction of bodies at the equator, where it bulges, and at the poles, where it is flattened. The improvement of telescopes has enabled us to ascertain the same fact with respect to the planets Jupiter and Saturn.

Besides unfolding the general laws which regulate the motions and figures of the heavenly bodies forming our Solar System, Astronomy consists in calculations of the places, times, and eclipses of those bodies, and their moons or *satellites* (from a Latin word signifying an *attendant*), and in observations of the Fixed Stars, which are innumerable assemblages of bodies, not moving round the Sun as our Earth and the other planets do, nor receiving the light they shine with from his light ; but shining, as the Sun and the Comets do, with a light of their own, and placed, to all appearance, immoveable, at immense distances from our world, that is, from our Solar System. Each of them is probably the sun of some other system like our own, composed of planets and their moons or satellites ; but so extremely distant from us, that they all are seen by us like one point of faint light, as you see two lamps placed a few inches asunder, only like one, when you view them a great way off. The number of the Fixed Stars is prodigious : even

to the naked eye they are very numerous, about 3000 being thus visible ; but when the heavens are viewed through the telescope, stars become visible in numbers wholly incalculable : 2000 are discovered in one of the small collections of a few visible stars called *Constellations* ; nay, what appears to the naked eye only a light cloud, as the *Milky Way*, when viewed through the telescope, proves to be an assemblage of innumerable Fixed Stars, each of them in all likelihood a sun and a system like the rest, though at an immeasurable distance from ours.

The size, and motions, and distances of the heavenly bodies are such as to exceed the power of ordinary imagination, from any comparison with the smaller things we see around us. The Earth's diameter is nearly 8000 miles in length ; but the Sun's is above 880,000 miles, and the bulk of the Sun is above 1,300,000 times greater than that of the Earth. The planet Jupiter, which looks like a mere speck, from his vast distance, is nearly 1300 times larger than the Earth. Our distance from the Sun is above 95 millions of miles ; but Jupiter is 490 millions, and Saturn 900 millions of miles distant from the Sun. The rate at which the Earth moves round the Sun is 68,000 miles an hour, or 140 times swifter than the motion of a cannon-ball ; and the planet Mercury, the nearest to the Sun, moves still quicker, nearly 110,000 miles an hour.



We, upon the Earth's surface, besides being carried round the Sun, move round the Earth's axis by the rotatory or spinning motion which it has; so that every 24 hours we move in this manner near 24,000 miles, beside moving round the Sun above 1,600,000 miles. These motions and distances, however, prodigious as they are, seem as nothing compared to those of the comets, one of which, when farthest from the Sun, is 11,200 millions of miles from him; and, when nearest the Sun, flies at the amazing rate of 880,000 miles an hour. Sir Isaac Newton calculated its heat at 2000 times that of red-hot iron; and that it would take thousands of years to cool. But the distance of the Fixed Stars is yet more vast: they have been supposed to be 400,000 times farther from us than we are from the Sun, that is 38 millions of millions of miles; so that a cannon-ball would take nearly nine millions of years to reach one of them, supposing there was nothing to hinder it from pursuing its course thither. As light takes about eight minutes and a quarter to reach us from the Sun, it would be above six years in coming from one of those stars; but the calculations of later astronomers prove some stars to be so far distant, that their light must take centuries before it can reach us; so that every particle of light which enters our eyes left the star it comes from three or four hundred years ago.)

Astronomers have, by means of their excellent glasses, aided by Geometry and calculations, been able to observe not only stars, planets, and their satellites, invisible to the naked eye, but to measure the height of mountains in the Moon, by observations of the shadows which those eminences cast on her surface ; and they have discovered volcanoes, or burning mountains, in the same body.

The tables, which they have by the like means been enabled to form of the heavenly motions, are of great use in navigation. By means of the eclipses of Jupiter's satellites, and by the tables of the Moon's motions, we can ascertain the position of a ship at sea ; for the observation of the Sun's height at mid-day gives the *latitude* of the place, that is, its distance from the equinoctial or equator, the line passing through the middle of the Earth's surface equally distant from both poles ; and these tables, with the observations of the satellites, or moons, give the distance east and west of the observatory for which the tables are calculated—called the *longitude* of the place : consequently the mariner can thus tell nearly in what part of the ocean he is, how far he has sailed from his port of departure, and how far he must sail, and in what direction, to gain the port of his destination. The advantage of this knowledge is therefore manifest in the common affairs of life ; but it sinks into insignificance compared with the vast extent of those views which the

contemplations of the science afford, of numberless worlds filling the immensity of space, and all kept in their places, and adjusted in their prodigious motions by the same simple principle, under the guidance of an all-wise and all-powerful Creator.

We have been considering the application of Dynamics to the motions of the heavenly bodies, which forms the science of *Physical Astronomy*. The application of Dynamics to the calculation, production, and direction of motion, forms the science of *Mechanics*, sometimes called *Practical Mechanics*, to distinguish it from the more general use of the word, which comprehends every thing that relates to motion and force. The fundamental principle of the science, upon which it mainly depends, flows immediately from a property of the circle already mentioned, and which, perhaps, appeared at the moment of little value,—that the lengths of circles are in proportion to their diameters. Observe how upon this simple truth nearly the whole of those contrivances are built by which the power of man is increased as far as solid matter assists him in extending it; and nearly the whole of those doctrines, too, by which he is enabled to explain the voluntary motions of animals, as far as these depend upon their own bodies. There can be nothing more instructive in showing the importance and fruitfulness of scientific truths, however trivial and forbidding they may at first

sight appear. For it is an immediate consequence of this property of the circle, that if a rod of iron, or beam of wood, or any other solid material, be placed on a point, or pivot, so that it may move as the arms of a balance do round its centre, or a seesaw board does round its prop, the two ends will go through parts of circles, each proportioned to that arm of the beam to which it belongs: the two circles will be equal if the pivot is in the centre or middle point of the beam; but if it is nearer one end than the other, say three times, that end will go through a circular space, or arch, three times shorter than the circular space the other end goes through in the same time. If, then, the end of the long beam goes through three times the space, it must move with three times the swiftness of the short beam's end, since both move in the same time; and therefore any force applied to the long end must overcome the resistance of three times that force applied at the opposite end, since the two ends move in contrary directions: hence one pound placed at the long end would balance three placed at the short end. The beam we have been supposing is called a *Lever*, and the same rule must evidently hold for all proportions of the lengths of its arms. If, then, the lever be seventeen feet long and the pivot, or *fulcrum* (as it is called, from the Latin word signifying *support*), be a foot from one end, an ounce placed on the other end will balance



pound placed on the near end ; and the least additional weight, or the slightest push or pressure on the far end, so loaded, will make the pound weight on the other move upwards. If, instead of an ounce, we place upon the end of the long arm the short arm of a second beam or lever supported by a fulcrum, one foot from it, and then place the long arm of this second lever upon the short arm of a third lever, whose fulcrum is one foot from it ; and if we put on the end of this third lever's long arm an ounce weight, that ounce will move upwards a pound on the second lever's long arm, and this moving upwards will cause the short arm to force downwards sixteen pounds at the long end of the first lever, which will make the short end of the first lever move upwards, though two hundred and fifty-six pounds be laid on it : the same thing continuing, a pound on the long arm of the third lever will move a ton and three-quarters on the short arm of the first lever ; that is, will balance it, so that the slightest pressure with the finger, or a touch from a child's hand, will move as much as two horses can draw. The lever is called, on this account, a *mechanical power* ; and there are five other mechanical powers, of most of which its properties form the foundation ; indeed they have all been resolved into combinations of levers. The pulley seems the most difficult to reduce under the principle of the lever. Thus the *wheel and axle* is

only a lever moving round an axle, and always retaining the effect gained during every part of the motion, by means of a rope wound round the butt end of the axle; the spoke of the wheel being the long arm of the lever, and the half diameter of the axle its short arm. By a combination of levers, wheels, pulleys, so great an increase of force is obtained, that, but for the obstruction from friction, and the resistance of the air, there could be no bounds to the effect of the smallest force thus multiplied; and to this fundamental principle Archimedes, one of the most illustrious mathematicians of ancient times, referred, when he boasted, that if he only had a pivot or fulcrum whereon he might rest his machinery, he could move the Earth. Upon so simple a truth, assisted by the aid derived from other sources, rests the whole fabric of mechanical power, whether for raising weights, or cleaving rocks, or pumping up rivers from the bowels of the earth; or, in short, performing any of those works to which human strength, even augmented by the help of the animals whom Providence has subdued to our use, would prove altogether inadequate.

The application of Dynamics to the pressure and motions of fluids, constitutes a science which receives different appellations according as the fluids are heavy and liquid like water, or light and invisible like air. In the former case it is called

*Hydrodynamics*, from the Greek words signifying *water*, and *power* or *force*; in the latter *Pneumatics*, from the Greek word signifying *breath* or *air*; and Hydrodynamics is divided into *Hydrostatics*, which treats of the weight and pressure of liquids, from the Greek words for *balancing* of *water*; and *Hydraulics*, which treats of their motion, from the Greek name for certain musical instruments played with *water* in *pipes*.

The discoveries to which experiments, aided by mathematical reasoning, have led, upon the pressure and motion of fluids, are of the greatest importance, whether we regard their application to practical purposes, or to their use for explaining the appearances in nature, or their singularity as the subjects of scientific contemplation. When it is found that the pressure of water or any other liquid upon the surface that contains it, is not in the least degree proportioned to its bulk, but only to the height at which it stands, so that a long small pipe, containing a pound or two of the fluid, will give the pressure of twenty or thirty tons; nay, of twice or thrice as much, if its length be increased and its bore lessened, without the least regard to the quantity of the liquid, we are not only astonished at so extraordinary and unexpected a property of matter, but we straightway perceive one of the great agents employed in the vast operations of nature, in which the most trifling

means are used to work the mightiest effects. We likewise learn to guard against many serious mischiefs in our own works, and to apply safely and usefully a power calculated, according as it is directed, either to produce unbounded devastation, or to render the most beneficial service.

Nor are the discoveries relating to the Air less interesting in themselves, and less applicable to important uses. It is an agent, though invisible, as powerful as Water, in the operations both of nature and of art. Experiments of a simple and decisive nature show the amount of its pressure to be between 14 and 15 pounds on every square inch; but, like all other fluids, it presses equally in every direction: so that though, on one hand, there is a pressure downwards of above 250 pounds, yet this is exactly balanced by an equal pressure upwards, from the air pressing round and getting below. If, however, the air on one side be removed, the whole pressure from the other acts unbalanced. Hence the ascent of water in pumps, which suck out the air from a barrel, and allow the pressure upon the water to force it up 32 or 33 feet, that body of water being equal to the weight of the atmosphere. Hence the ascent of the mercury in the barometer is only 28 or 29 inches, mercury being between 13 and 14 times heavier than water. Hence, too, the motion of the steam-engine; the piston of which, until the direct force of steam was



applied, used to be pressed downwards by the weight of the atmosphere from above, all air being removed below it by first filling it with steam, and then suddenly cooling and converting that steam into water, so as to leave nothing in the space it had occupied. Hence, too, the power which some animals possess of walking along the perpendicular surfaces of walls, and even the ceilings of rooms, by squeezing out the air between the inside of their feet and the wall, and thus being supported by the pressure of the air against the outside of their feet.

The science of *Optics*, (from the Greek word for *seeing*,) which teaches the nature of light, and of the sensation conveyed by it, presents, of itself, a field of unbounded extent and interest. To it the arts, and the other sciences, owe those most useful instruments which have enabled us at once to examine the minutest parts of the structure of animal and vegetable bodies, and to calculate the size and the motions of the most remote of the heavenly bodies. But as an object of learned curiosity, nothing can be more singular than the fundamental truth discovered by the genius of Newton,—that the light, which we call white, is in fact composed of all the colours, blended in certain proportions; unless, perhaps, it be that astonishing conjecture of his unrivalled sagacity, by which he descried the inflammable nature of the

diamond, and its belonging, against all appearance of probability, to the class of oily substances, from having observed, that it stood among them, and far removed from all crystals, in the degree of its action upon light; a conjecture turned into certainty by discoveries made a century afterwards.

To a man who, for original genius and strong natural sense, is not unworthy of being named after this illustrious sage, we owe the greater part of *Electrical* science. It treats of the peculiar substance, resembling both light and heat, which, by rubbing, is found to be produced in a certain class of bodies, as glass, wax, silk, amber; and to be conveyed easily or *conducted* through others, as wood, metals, water; and it has received the name of *Electricity*, from the Greek word for *amber*. Dr. Franklin discovered that this is the same matter which, when collected in the clouds, and conveyed from them to the earth, we call *lightning*, and whose noise, in darting through the air, is *thunder*. The observation of some movements in the limbs of a dead frog gave rise to the discovery of *Animal Electricity*, or *Galvanism*, as it was at first called from the name of the discoverer; and which has of late years given birth to improvements that have changed the face of chemical philosophy; affording a new proof how few there are of the processes of nature incapable of repaying the labour we bestow in patiently and diligently examining them. It is

to the results of the remark accidentally made upon the twitching in the frog's leg, not, however, hastily dismissed and forgotten, but treasured up and pursued through many an elaborate experiment and calculation, that we owe our acquaintance with the extraordinary metal, liquid like mercury, lighter than water, and more inflammable than phosphorus, which forms, when it burns by mere exposure to the air, one of the salts best known in commerce, and the principal ingredient in saltpetre.

In order to explain the nature and objects of those branches of Natural Science more or less connected with the mathematics, some details were necessary, as without them it was difficult immediately to perceive their importance, and, as it were, relish the kind of instruction which they afford. But the same course needs not be pursued with respect to the other branches. The value and the interest of chemistry is at once perceived, when it is known to teach the nature of all bodies ; the relations of simple substances to heat and to one another, or their combinations together ; the composition of those which nature produces in a compound state ; and the application of the whole to the arts and manufactures. Some branches of philosophy, again, are chiefly useful and interesting to particular classes, as surgeons and physicians. Others are easily understood by a knowledge of the principles of

Mechanics and Chemistry, of which they are applications and examples; as those which teach the structure of the earth and the changes it has undergone; the motions of the muscles, and the structure of the parts of animals; the qualities of animal and vegetable substances; and that department of Agriculture which treats of soils, manure, and machinery. Other branches are only collections of facts, highly curious and useful indeed, but which any one who reads or listens, perceives as clearly, and comprehends as readily, as the professed student. To this class belongs Natural History, in so far as it describes the habits of animals and plants, and its application to that department of Agriculture which treats of cattle and their management.

#### IV. APPLICATION OF NATURAL SCIENCE TO THE ANIMAL AND VEGETABLE WORLD.

BUT, for the purpose of further illustrating the advantages of Philosophy, its tendency to enlarge the mind, as well as to interest it agreeably, and afford pure and solid gratification, a few instances may be given of the singular truths brought to light by the application of Mathematical, Mechanical, and Chemical knowledge to the habits of animals and plants; and some examples may be



added of the more ordinary and easy, but scarcely less interesting observations, made upon those habits, without the aid of the profounder sciences.

We may remember the curve line which mathematicians call a Cycloid. It is the path which any point of a circle, moving along a plane, and round its centre, traces in the air ; so that the nail on the felly of a cart-wheel moves in a Cycloid, as the cart goes along, and as the wheel itself both turns round its axle and is carried along the ground. Now this curve has certain properties of a peculiar and very singular kind with respect to motion. One is, that if any body whatever moves in a cycloid by its own weight or swing, together with some other force acting upon it all the while, it will go through all distances of the same curve in exactly the same time ; and, accordingly, pendulums have sometimes been contrived to swing in such a manner, that they shall describe cycloids, or curves very near cycloids, and thus move in equal times, whether they go through a long or a short part of the same curve. Again, if a body is to descend from any one point to any other, not in the perpendicular, by means of some force acting on it together with its weight, the line in which it will go the quickest of all will be the cycloid ; not the straight line, though that is the shortest of all

lines which can be drawn between the two points ; nor any other curve whatever, though many are much flatter, and therefore shorter than the cycloid—but the cycloid, which is longer than many of them, is yet, of all curved or straight lines which can be drawn, the one the body will move through in the shortest time. Suppose, again, that the body is to move from one point to another, by its weight and some other force acting together, but to go through a certain space,—as a hundred yards,—the way it must take to do this, in the shortest time possible, is by moving in a cycloid ; or the length of a hundred yards must be drawn into a cycloid, and then the body will descend through the hundred yards in a shorter time than it could go the same distance in any other path whatever. Now, it is believed that Birds, as the Eagle, which build in the rocks, drop or fly down from height to height in this course. It is impossible to make very accurate observations of their flight and path ; but there is a general resemblance between the course they take and the cycloid, which has led ingenious men to adopt this opinion.

If we have a certain quantity of any substance, a pound of wood, for example, and would fashion it in the shape to take the least room, we must make a globe of it ; it will in this figure have the

smallest surface. But suppose we want to form the pound of wood, so that in moving through the air or water it shall meet with the least possible resistance ; then we must lengthen it out for ever, till it becomes not only like a long-pointed pin, but thinner and thinner, longer and longer, till it is quite a straight line, and has no perceptible breadth or thickness at all. If we would dispose of the given quantity of matter, so that it shall have a certain length only, say a foot, and a certain breadth at the thickest part, say three inches, and move through the air or water with the smallest possible resistance which a body of those dimensions can meet, then we must form it into a figure of a peculiar kind called the *Solid of least resistance*, because, of all the shapes that can be given to the body, its length and breadth remaining the same, this is the one which will make it move with the least resistance through the air, or water, or other fluid. A very difficult chain of mathematical reasoning, by means of the highest branches of algebra, leads to a knowledge of the curve which, by revolving on its axis, makes a solid of this shape, in the same way that a circle, by so revolving, makes a sphere or globe ; and the curve certainly resembles closely the face or head part of a fish. Nature, therefore, (by which we always mean the Divine Author of nature,) has fashioned these fishes so, that, according to mathematical

principles, they swim the most easily through the element they live and move in.\*

Suppose upon the face part of one of these fishes a small insect were bred, endowed with faculties sufficient to reason upon its condition, and upon the motion of the fish it belonged to, but never to have discovered the whole size and shape of the face part; it would certainly complain of the form as clumsy, and fancy that it could have made the fish so as to move with less resistance. Yet if the whole shape were disclosed to it, and it could discover the principle on which that shape was preferred, it would at once perceive, not only that what had seemed clumsy was skilfully contrived, but that, if any other shape whatever had been taken, there would have been an error committed; nay, *that there must of necessity* have been an error; and that the very best possible arrangement had been adopted. So it may be with man in the universe, where, seeing only a part of the great system, he fancies there is evil; and yet, if he were permitted to survey the whole, what had seemed imperfect might appear to be necessary for the general perfection, insomuch that any other arrangement, even of that seemingly imperfect part, must needs have rendered the whole less perfect.

\* The feathers of the wings of birds are found to be placed at the *best possible* angle for helping on the bird by their action on the air.



The common objection is, that what seems evil *might have* been avoided; but in the case of the fish's shape, it *could not* have been avoided.

It is found by optical inquiries, that the particles or rays of light, in passing through transparent substances of a certain form, are bent to a point where they make an image or picture of the shining bodies they come from, or of the dark bodies they are reflected from. Thus, if a pair of spectacles be held between a candle and the wall, they make two images of the candle upon it; and if they be held between the window and a sheet of paper when the sun is shining, they make a picture on the paper of the houses, trees, fields, sky, and clouds. The eye is found to be composed of several natural magnifiers which make a picture on a membrane at the back of it, and from this membrane there goes a nerve to the brain, conveying the impression of the picture, by means of which we see. Now, white light was discovered by Newton to consist of differently-coloured parts, which are differently bent in passing through transparent substances, so that the lights of several colours come to a point at different distances, and thus create an indistinct image at any one distance. This was long found to make our telescopes imperfect, inso-much that it became necessary to make them of reflectors or mirrors, and not of magnifying glasses, the same difference not being observed to affect the

reflection of light. But another discovery was, about fifty years afterwards, made by Mr. Dollond, —that, by combining different kinds of glass in a compound magnifier, the difference may be greatly corrected; and on this principle he constructed his telescopes. It is found, too, that the different natural magnifiers of the eye are combined upon a principle of the same kind. Thirty years later, a third discovery was made by Mr. Blair, of the greatly superior effect which combinations of different liquids have in correcting the imperfection; and, most wonderful to think, when the eye is examined, we find it consists of different liquids, acting naturally upon the same principle which was thus recently found out in optics by many ingenious mechanical and chemical experiments.

Again, the point to which any magnifier collects the light is more or less distant as the magnifier is flatter or rounder, so that a small globe of glass or any transparent substance makes a microscope. And this property of light depends upon the nature of lines, and is purely of a mathematical nature, after we have once ascertained by experiment, that light is bent in a certain way when it passes through transparent bodies. Now birds flying in the air, and meeting with many obstacles, has branches and leaves of trees, require to have their eyes sometimes as flat as possible for protection; but sometimes as round as possible, that they

may see the small objects, flies and other insects, which they are chasing through the air, and which they pursue with the most unerring certainty. This could only be accomplished by giving them a power of suddenly changing the form of their eyes. Accordingly, there is a set of hard scales placed on the outer coat of their eye, round the place where the light enters; and over these scales are drawn the muscles or fibres by which motion is communicated; so that, by acting with these muscles, the bird can press the scales, and squeeze the natural magnifier of the eye into a round shape when it wishes to follow an insect through the air, and can relax the scales, in order to flatten the eye again, when it would see a distant object, or move safely through leaves and twigs. This power of altering the shape of the eye is possessed by birds of prey in a very remarkable degree. They can thus see the smallest objects close to them, and can yet discern larger bodies at vast distances, as a carcass stretched upon the plain, or a dying fish afloat on the water.

A singular provision is made for keeping the surface of the bird's eye clean—for wiping the glass of the instrument, as it were—and also for protecting it, while rapidly flying through the air and through thickets, without hindering the sight. Birds are, for these purposes, furnished with a third eyelid, a fine membrane or skin, which is con-

stantly moved very rapidly over the eyeball by two muscles placed in the back of the eye. One of the muscles ends in a loop, the other in a string which goes through the loop, and is fixed in the corner of the membrane, to pull it backward and forward. If you wish to draw a thing towards any place with the least force, you must pull directly in the line between the thing and the place; but if you wish to draw it as quickly as possible, and with the most convenience, and do not regard the loss of force, you must pull it obliquely, by drawing it in two directions at once. Tie a string to a stone, and draw it straight towards you with one hand; then, make a loop on another string, and running the first through it, draw one string in each hand, not towards you, but sideways, till both strings are stretched in a straight line: you will see how much more easily the stone moves quickly than it did before when pulled straight forward. Again, if you tie strings to the two ends of a rod, or slip of card, in a running groove, and bring them to meet and pass through a ring or hole, for every inch in a straight line that you draw both together below the ring, the rod will move onward two. Now this is proved, by mathematical reasoning, to be the necessary consequence of forces applied obliquely: there is a loss of power, but a great gain in velocity and convenience. This is the thing required to be gained in the third eyelid,



and the contrivance is exactly that of a string and a loop, moved each by a muscle, as the two strings are by the hands in the cases we have been supposing.

A third eyelid of the same kind is found in the horse, and called the *haw*; it is moistened with a pulpy substance (or mucilage) to take hold of the dust on the eyeball, and wipe it clear off; so that the eye is hardly ever seen with anything upon it, though greatly exposed from its size and posture. The swift motion of the haw is given to it by a gristly elastic substance placed between the eyeball and the socket, and striking obliquely, so as to drive out the haw with great velocity over the eye, and then let it come back as quickly. Ignorant persons, when this haw is inflamed from cold, and swells so as to appear, which it never does in a healthy state, often mistake it for an imperfection, and cut it off: so nearly do ignorance and cruelty produce the same mischief.

If any quantity of matter, as a pound of wood or iron, is fashioned into a rod of a certain length, say one foot, the rod will be strong in proportion to its thickness; and, if the figure is the same, that thickness can only be increased by making it hollow. Therefore hollow rods or tubes, of the same length and quantity of matter, have more strength than solid ones. This is a principle so well understood now, that engineers make their axles and other parts of machinery hollow, and therefore stronger

with the same weight than they would be if thinner and solid. Now the bones of animals are all more or less hollow ; and are therefore stronger with the same weight and quantity of matter than they otherwise would be. But birds have the largest bones in proportion to their weight ; their bones are more hollow than those of animals which do not fly ; and therefore they have the needful strength without having to carry more weight than is absolutely necessary. Their quills derive strength from the same construction. They possess another peculiarity to help their flight. No other animals have any communication between the air-vessels of their lungs and the hollow parts of their bodies ; but birds have it ; and by this means they can blow out their bodies as we do a bladder, and thus become lighter when they would either make their flight towards the ground slower, or rise more swiftly, or float more easily in the air ; while, by lessening their bulk and closing their wings, they can drop more speedily if they wish to chase or to escape. Fishes possess a power of the same kind, though not by the same means. They have *air-bladders* in their bodies, and can puff them out, or press them closer, at pleasure : when they want to rise in the water, they fill out the bladder, and this lightens them ; when they would sink, they squeeze the bladder, pressing the air into a smaller space, and this makes them heavier. If the bladder

breaks, the fish remains at the bottom, and can be held up only by the most laborious exertions of the fins and tail. Accordingly, flat fish, such as skaits and flounders, which have no air-bladders, seldom rise from the bottom, but are found lying on banks in the sea, or at the bottom of rivers.

If you have a certain space, as a room, to fill up with closets or little cells, all of the same size and shape, there are only three figures which will answer, and enable you to fill the room without losing any space between the cells; they must either be squares, or figures of three equal sides, or figures of six equal sides. With any other figures whatever, space would be lost between the cells. This is evident upon considering the matter; and it is proved by mathematical reasoning. The six-sided figure is by far the most convenient of those three shapes, because its corners are flatter, and any round body placed in it has therefore more space, less room being lost in the corners. This figure, too, is the strongest of the three; any pressure from without or from within will hurt it least, as it has something of the strength of an arch. A round figure would be still stronger, but then room would be lost between the circles, whereas with the six-sided figure none is lost. Now, it is a most remarkable fact, that *Bees* build their cells exactly in this shape, and thereby save both room and materials beyond what they could save if

they built in any other shape whatever. They build in the very best possible shape for their purpose, which is to save all the room and all the wax they can. So far as to the shape of the walls of each cell; but the roof and floor, or top and bottom, are built on equally true principles. It is proved by mathematicians, that, to give the greatest strength, and save the most room, the roof and floor must be made of three square planes meeting in a point; and they have further proved, by a demonstration belonging to the highest parts of Algebra, that there is one particular angle or inclination of those planes to each other where they meet, which makes a greater saving of materials and of work than any other inclination whatever could possibly do. Now, the Bees actually make the tops and bottoms of their cells of three planes meeting in a point; and the inclinations or angles at which they meet are precisely those found out by the mathematicians to be the best possible for saving wax and work.\*

\* Koenig, pupil of Bernoulli, and Maclaurin, proved by very refined investigations, carried on with the aid of the fluxional calculus, that the obtuse angle must be  $109^{\circ} 28'$ , and the acute  $70^{\circ} 32'$ , to save the most wax and work possible. Maraldi found by actual measurement, that the angles are *about*  $110^{\circ}$  and  $70^{\circ}$ . These angles never vary in any place; and it is scarcely less singular, that the breadth of all bees' cells are everywhere precisely the same, the drone or male cells being  $\frac{5}{18}$ ths and the worker or female cells  $\frac{13}{80}$ ths of an inch in breadth, and this in all countries and times.



Who would dream of the bee knowing the highest branch of the Mathematics—the fruit of Newton's most wonderful discovery—a result, too, of which he was himself ignorant, one of his most celebrated followers having found it out in a later age? This little insect works with a truth and correctness which are perfect, and according to the principles at which man has arrived only after ages of slow improvement in the most difficult branch of the most difficult science. But the Mighty and All-wise Creator, who made the insect and the philosopher, bestowing reason on the latter, and giving the former to work without it—to Him all truths are known to all eternity, with an intuition that mocks even the conceptions of the sagest of human kind.

It may be recollected, that when the air is exhausted or sucked out of any vessel, there is no longer the force necessary to resist the pressure of the air on the outside; and the sides of the vessels are therefore pressed inwards with violence: a flat glass would thus be broken, unless it were very thick; a round one, having the strength of an arch, would resist better; but any soft substance, as leather or skin, would be crushed or squeezed together at once. If the air was only sucked out slowly, the squeezing would be gradual; or, if it were only half sucked out, the skin would only be partly squeezed together. This is the process by

which *Bees* reach the fine dust and juices of hollow flowers, like the honeysuckle, and some kinds of long fox-glove, which are too narrow for them to enter. They fill up the mouth of the flower with their bodies, and suck out the air, or at least a large part of it; this makes the soft sides of the flower close, and squeezes the dust and juice towards the insect as well as a hand could do, if applied to the outside.

We may remember this pressure or weight of the atmosphere as shown by the barometer and the sucking-pump. Its weight is near fifteen pounds on every square inch, so that if we could entirely squeeze out the air between our two hands, they would cling together with a force equal to the pressure of double this weight, because the air would press upon both hands; and if we could contrive to suck or squeeze out the air between one hand and the wall, the hand would stick fast to the wall, being pressed on it with the weight of above two hundredweight, that is, near fifteen pounds on every square inch of the hand. Now, by a late most curious discovery of Sir Everard Home, the distinguished anatomist, it is found that this is the very process by which *Flies* and other insects of a similar description are enabled to walk up perpendicular surfaces, however smooth, as the sides of walls and panes of glass in windows, and to walk as easily along the ceiling of a room with their bodies downwards and their feet over

head. Their feet, when examined by a microscope, are found to have flat skins or flaps, like the feet of web-footed animals, as ducks and geese; and they have by means of strong folds the power of drawing the flap close down upon the glass or wall the fly walks on, and thus squeezing out the air completely, so as to make a vacuum between the foot and the glass or wall. The consequence of this is, that the air presses the foot on the wall with a very considerable force compared to the weight of the fly; for if its feet are to its body in the same proportion as ours are to our bodies, since we could support by a single hand on the ceiling of the room (provided it made a vacuum) more than our whole weight, namely, a weight of above fifteen stone, the fly can easily move on four feet in the same manner by help of the vacuum made under its feet.

It has likewise been found that some of the larger *Sea-animals* are by the same construction, only upon a greater scale, enabled to climb the perpendicular and smooth surfaces of the ice hills among which they live. Some kinds of *Lizard* have a like power of climbing, and of creeping with their bodies downwards along the ceiling of a room; and the means by which they are enabled to do so are the same. In the large feet of those animals, the contrivance is easily observed, of the toes and muscles, by which the skin of the foot is

pinned down, and the air excluded in the act of walking or climbing; but it is the very same, only upon a larger scale, with the mechanism of a fly's or a butterfly's foot; and both operations, the climbing of the sea-horse on the ice, and the creeping of the fly on the window or the ceiling, are performed exactly by the same power, the weight of the atmosphere, which causes the quicksilver to stand in the weather-glass, the wind to whistle through a key-hole, and the piston to descend in an old steam-engine.

Although philosophers are not agreed as to the peculiar action which light exerts upon vegetation, and there is even some doubt respecting the decomposition of air and water during that process, one thing is undeniable,—the necessity of light to the growth and health of plants: without it they have neither colour, taste, nor smell; and accordingly they are for the most part so formed as to receive it at all times when it shines on them. Their cups, and the little assemblages of their leaves before they sprout, are found to be more or less affected by the light, so as to open and receive it. In several kinds of plants this is more evident than in others; their flowers close entirely at night, and open in the day. Some constantly turn round towards the light, following the sun, as it were, while he makes or seems to make his revolution, so that they receive the greatest quantity possible



of his rays. Thus clover in a field follows the apparent course of the sun. But all leaves of plants turn to the sun, place them how you will, light being essential to their thriving.

The lightness of inflammable gas is well known. When bladders of any size are filled with it, they rise upwards, and float in the air. Now, it is a most curious fact, ascertained by Mr. Knight, that the fine dust, by means of which plants are impregnated one from another, is composed of very small globules, filled with this gas—in a word, of small air-balloons. These globules thus float from the male plant through the air, and striking against the females, are detained by a glue prepared on purpose to stop them, which no sooner moistens the globules than they explode, and their substance remains, the gas flying off which enabled them to float. A provision of a very simple kind is also, in some cases, made to prevent the male and female blossoms of the same plant from breeding together, this being found to hurt the breed of vegetables, just as breeding in and in spoils the race of animals. It is contrived that the dust shall be shed by the male blossom before the female of the same plant is ready to be affected by it; so that the impregnation must be performed by the dust of some other plant, and in this way the breed be crossed. The light gas with which the globules are filled is most essential to the operation, as it

conveys them to great distances. A plantation of yew-trees has been known, in this way, to impregnate another several hundred yards off.

The contrivance by which some creeper plants are enabled to climb walls, and fix themselves, deserves attention. The *Virginia creeper* has a small tendril, ending in a claw, each toe of which has a knob, thickly set with extremely small bristles; they grow into the invisible pores of the wall, and swelling, stick there as long as the plant grows, and prevent the branch from falling; but when the plant dies, they become thin again, and drop out, so that the branch falls down.

The *Vanilla* plant of the West Indies climbs round trees likewise by means of tendrils; but when it has fixed itself, the tendrils drop off, and leaves are formed.

It is found by chemical experiments, that the juice which is in the stomachs of animals (called the *gastric* juice, from a Greek word signifying *the belly*) has very peculiar properties. Though it is for the most part a tasteless, clear, and seemingly a very simple liquor, it nevertheless possesses extraordinary powers of dissolving substances which it touches or mixes with; and it varies in different classes of animals. In one particular it is the same in all animals; it will not attack living matter, but only dead; the consequence of which is, that its powers of eating away and dissolving are perfectly

safe to the animals themselves, in whose stomachs it remains without ever hurting them. This juice differs in different animals according to the food on which they subsist ; thus, in birds of prey, as kites, hawks, owls, it only acts upon animal matter, and does not dissolve vegetables. In other birds, and in all animals feeding on plants, as oxen, sheep, hares, it dissolves vegetable matter, as grass, but will not touch flesh of any kind. This has been ascertained by making them swallow balls with meat in them, and several holes drilled through to let the gastric juice reach the meat : no effect was produced upon it. We may further observe, that there is a most curious and beautiful correspondence between this juice in the stomach of different animals and the other parts of their bodies, connected with the important operations of eating and digesting their food. The use of the juice is plainly to convert what they eat into a fluid, from which, by various other processes, all their parts, blood, bones, muscles, &c., are afterwards formed. But the food is first of all to be obtained, and then prepared by bruising, for the action of the juice. Now birds of prey have instruments, their claws and beaks, for tearing and devouring their food (that is, animals of various kinds), but those instruments are useless for picking up and crushing seeds ; accordingly they have a gastric juice which dissolves the animals they eat ;

while birds which have only a beak fit for pecking, and eating seeds, have a juice that dissolves seeds, and not flesh. Nay more, it is found that the seeds must be bruised before the juice will dissolve them : this you find by trying the experiment in a vessel with the juice ; and accordingly the birds have a gizzard, and animals which graze have flat teeth, which grind and bruise their food, before the gastric juice is to act upon it.

We have seen how wonderfully the *Bee* works, according to rules discovered by man thousands of years after the insect had been following them with perfect accuracy. The same little animal seems to be acquainted with principles of which we are still ignorant. We can, by crossing, vary the forms of cattle with astonishing nicety ; but we have no means of altering the nature of an animal once born, by means of treatment and feeding. This power, however, is undeniably possessed by the bees. When the queen bee is lost by death or otherwise, they choose a grub from among those which are born for workers ; they make three cells into one, and placing the grub there, they build a tube round it ; they afterwards build another cell of a pyramidal form, into which the grub grows ; they feed it with peculiar food, and tend it with extreme care. It becomes, when transformed from the worm to the fly, not a worker, but a queen bee.

These singular insects resemble our own species



in one of our worst propensities, the disposition to war; but their attention to their sovereign is equally extraordinary, though of a somewhat capricious kind. In a few hours after their queen is lost, the whole hive is in a state of confusion. A singular humming is heard, and the bees are seen moving all over the surface of the combs with great rapidity. The news spreads quickly, and when the queen is restored, quiet immediately succeeds. But if another queen is put upon them, they instantly discover the trick, and, surrounding her, they either suffocate or starve her to death. This happens if the false queen is introduced within a few hours after the first is lost or removed; but if twenty-four hours have elapsed, they will receive any queen, and obey her.

The labours and the policy of the *Ants* are, when closely examined, still more wonderful, perhaps, than those of the *Bees*. Their nest is a city consisting of dwelling-places, halls, streets, and squares into which the streets open. The food they principally like is the honey which comes from another insect found in their neighbourhood, and which they, generally speaking, bring home from day to day as they want it. Late discoveries have shown that they do not eat grain, but live almost entirely on animal food and this honey. Some kinds of ants have the foresight to bring home the insects on whose honey they feed, and keep them

in particular cells, where they guard them to prevent their escaping, and feed them with proper vegetable matter which they do not eat themselves. Nay, they obtain the eggs of those insects, and superintend their hatching, and then rear the young insect until he becomes capable of supplying the desired honey. They sometimes remove them to the strongest parts of their nest, where there are cells apparently fortified for protecting them from invasion. In those cells the insects are kept to supply the wants of the whole ants which compose the population of the city. It is a most singular circumstance in the economy of nature, that the degree of cold at which the ant becomes torpid is also that at which this insect falls into the same state. It is considerably below the freezing-point; so that they require food the greater part of the winter, and if the insects on which they depend for food were not kept alive during the cold in which the ants can move about, the latter would be without the means of subsistence.

How trifling soever this little animal may appear in our climate, there are few more formidable creatures than the ant of some tropical countries. A traveller, who lately filled a high station in the French government, Mr. Malouet, has described one of their cities, and, were not the account confirmed by various testimonies, it might seem exaggerated. He observed at a great distance what

seemed a lofty structure, and was informed by his guide that it consisted of an ant-hill, which could not be approached without danger of being devoured. Its height was from fifteen to twenty feet, and its base thirty or forty feet square. Its sides inclined like the lower part of a pyramid, the point being cut off. He was informed that it became necessary to destroy these nests, by raising a sufficient force to dig a trench all round, and fill it with fagots, which were afterwards set on fire; and then battering with cannon from a distance, to drive the insects out and make them run into the flames. This was in South America; and African travellers have met them in the same formidable numbers and strength.

The older writers of books upon the habits of some animals abound with stories which may be of doubtful credit. But the facts now stated, respecting the Ant and Bee, may be relied on as authentic. They are the result of very late observations, and experiments made with great accuracy by several most worthy and intelligent men; and the greater part of them have the confirmation arising from more than one observer having assisted in the inquiries.\* The habits of *Beavers* are equally

\* A singular circumstance occasioned this in the case of Mr. Huber, by far the most eminent of these naturalists: he was quite blind, and performed all his experiments by means of assistants.

well-authenticated, and, being more easily observed, are vouched by a greater number of witnesses. These animals, as if to enable them to live and move either on land or water, have two web-feet like those of ducks or water-dogs, and two like those of land animals. When they wish to construct a dwelling-place, or rather city, for it serves the whole body, they choose a level ground with a stream running through it; they then dam up the stream so as to make a pond, and perform the operation as skilfully as we could ourselves. Next they drive into the ground stakes of five or six feet long in rows, wattling each row with twigs, and puddling or filling the interstices with clay, which they ram close in, so as to make the whole solid and water-tight. This dam is likewise shaped on the truest principles; for the upper side next the water slopes, and the side below is perpendicular: the base of the dam is ten or twelve feet thick; the top or narrow part two or three, and it is sometimes as long as one hundred feet.\* The pond

\* If the base is twelve, and the top three feet thick, and the height six feet, the face must be the side of a right-angled triangle whose height is eight feet. This would be the exact proportion which there ought to be, upon mathematical principles, to give the greatest resistance possible to the water in its tendency to turn the dam round, provided the materials of which it is made were lighter than water in the proportion of 44 to 100. But the materials are probably more than twice as heavy as water, and the form of so flat a



being thus formed and secured, they make their houses round the edge of it ; they are cells, with vaulted roofs, and upon piles : they are made of stones, earth, and sticks ; the walls are two feet thick, and plastered as neatly as if the trowel had been used. Sometimes they have two or three stories for retreating to in case of floods ; and they always have two doors, one towards the water and one towards the land. They keep their winter provisions in stores, and bring them out to use ; they make their beds of moss ; they live on the bark of trees, gum, and crawfish. Each house holds from twenty to thirty, and there may be from ten to twenty-five houses in all. Some of their communities are larger than others, but there are seldom fewer than two or three hundred inhabitants. In working they all bear their shares ; some gnaw the trees and branches with their teeth to form stakes and beams ; others roll the pieces to the water ; others, diving, make holes with their teeth to place the piles in ; others collect and carry stones and clay ; others beat and mix the mortar ; and dike is taken, in all likelihood, in order to guard against a more imminent danger—that of the dam being carried away by being shoved forwards. We cannot calculate what the proportions are which give the greatest possible resistance to this tendency, without knowing the tenacity of the materials, as well as their specific gravity. It may very probably be found that the construction is such as to secure the most completely against the two pressures at the same time.

others carry it on their broad tails, and with these beat it and plaster it. Some superintend the rest, and make signals by sharp strokes with the tail, which are carefully attended to; the beavers hastening to the place where they are wanted to work, or to repair any hole made by the water, or to defend themselves or make their escape, when attacked by an enemy.

The fitness of different animals, by their bodily structure, to the circumstances in which they are found, presents an endless subject of curious inquiry and pleasing contemplation. Thus, the *Camel*, which lives in sandy deserts, has broad spreading hoofs to support him on the loose soil; and an apparatus in his body by which water is kept for many days, to be used when no moisture can be had. As this would be useless in the neighbourhood of streams or wells, and as it would be equally so in the desert, where no water is to be found, there can be no doubt that it is intended to assist in journeying across the sands from one watered spot to another. There is a singular and beautiful provision made in this animal's foot, for enabling it to sustain the fatigue of journeys under the pressure of its great weight. Besides the yielding of the bones and ligaments, or bindings, which gives elasticity to the foot of the deer and other animals, there is in the Camel's foot, between the horny sole and the bones, a cushion, like a ball, of

soft matter, almost fluid, but in which there is a mass of threads extremely elastic, interwoven with the pulpy substance. The cushion thus easily changes its shape when pressed, yet it has such an elastic spring, that the bones of the foot press on it uninjured by the heavy body which they support, and this huge animal steps as softly as a cat.

Nor need we flee to the desert in order to witness an example of skilful structure: the limbs of the *Horse* display it strikingly. The bones of the foot are not placed directly under the weight; if they were in an upright position, they would make a firm pillar, and every motion would cause a shock. They are placed slanting or oblique, and tied together by an elastic binding on their lower surfaces, so as to form springs as exact as those which we make of leather and steel for carriages. Then the flatness of the hoof, which stretches out on each side, and the frog coming down in the middle between the quarters, adds greatly to the elasticity of the machine. Ignorant of this, ill-informed farriers nail the shoe in such a manner as to fix the quarters, and cause permanent contraction of the bones, ligaments, and hoof—so that the elasticity is destroyed; every step is a shock; inflammation and lameness ensue.\*

\* Mr. Bracey Clarke has contrived an expanding shoe, which, by a joint in front, opens and contracts so as to obviate the evils of the common process.

The *Rein-deer* inhabits a country covered with snow the greater part of the year. Observe how admirably its hoof is formed for going over that cold and light substance, without sinking in it or being frozen. The under side is covered entirely with hair, of a warm and close texture; and the hoof, altogether, is very broad, acting exactly like the snow-shoes which men have constructed for giving them a larger space to stand on than their feet, and thus avoid sinking. Moreover, the deer spreads the hoof as wide as possible when it touches the ground: but, as this breadth would be inconvenient in the air, by occasioning a greater resistance while he is moving along, no sooner does he lift the hoof than the two parts into which it is cloven fall together, and so lessen the surface exposed to the air, just as we may recollect the birds doing with their bodies and wings. The shape and structure of the hoof are also well adapted to scrape away the snow, and enable the animal to get at the particular kind of moss (or *lichen*) on which he feeds. This plant, unlike others, is in its full growth during the winter season; and the *Rein-deer* accordingly thrives, from its abundance, at the season of his greatest use to man, notwithstanding the unfavourable effects of extreme cold upon the animal system.

There are some insects, of which the males have wings, and the females are grubs or worms. Of



these, the *Glow-worm* is the most remarkable: it is the female, and the male is a fly, which would be unable to find her out, creeping as she does in the dark lanes, but for the shining light which she gives to attract him.

There is a singular fish found in the Mediterranean, called the *Nautilus*, from its skill in navigation. The back of its shell resembles the hulk of a ship; on this it throws itself, and spreads two thin membranes to serve for two sails, paddling itself on with its feet or feelers, as oars.

The *Ostrich* lays and hatches her eggs in the sands: her form being ill-adapted for sitting on them, she has a natural oven furnished by the sand, and the strong heat of the sun. The *Cuckoo* is known to build no nest for herself, but to lay in the nests of other birds; but late observations show that she does not lay indiscriminately in the nests of all birds; she only chooses the nests of those which have bills of the same kind with herself, and therefore feed on the same kind of food. The *Duck*, and other birds breeding in muddy places, have a peculiar formation of the bill: it is both made so as to act like a strainer, separating the finer from the grosser parts of the liquid, and it is more furnished with nerves near the point than the bills of birds which feed on substances more exposed to the light; so that being more sensitive, it serves better to grope in the dark stream for food.

The bill of the *Snipe* is covered with a curious network of nerves for the same purpose; but the most singular provision of this kind is observed in a bird called the *Toucan*, or *Egg-sucker*, which chiefly feeds on the eggs found in birds' nests, and in countries where these are very deep and dark. Its bill is broad and long; when examined, it appears completely covered with branches of nerves in all directions; so that, by groping in a deep and dark nest it can feel its way as accurately as the finest and most delicate finger could. Almost all kinds of birds build their nests of materials found where they inhabit, or use the nests of other birds; but the *Swallow of Java* lives in rocky caverns on the sea, where there are no materials at all for the purpose of building. It is therefore so formed as to secrete in its body a kind of slime with which it makes a nest, much prized as a delicate food in Eastern countries.

Plants, in many remarkable instances, are provided for by equally wonderful and skilful contrivances. There is one, the *Muscipula*, *Fly-trap*, or *Fly-catcher*, which has small prickles in the inside of two leaves, or half leaves, joined by a hinge; a juice or syrup is provided on their inner surface, which acts as a bait to allure flies. There are several small spines or prickles standing upright in this syrup, and upon the only part of each leaf that is sensitive to the touch. When the fly, there-

fore, settles upon this part, its touching, as it were, the spring of the trap, occasions the leaves to shut and kill and squeeze the insect; whose juices and the air arising from their rotting serve as food to the plant.

In the West Indies, and in other hot countries of South America, where rain sometimes does not fall for a great length of time, a kind of plant called the *Wild-pine* grows upon the branches of the trees, and also on the bark of the trunk. It has hollow or bag-like leaves so formed as to make little reservoirs of water, the rain falling into them through channels which close at the top when full, and prevent it from evaporating. The seed of this useful plant has small floating threads, by which, when carried through the air, it catches any tree in the way, and falls on it and grows. Wherever it takes root, though on the under side of a bough, it grows straight upwards, otherwise the leaves would not hold water. It holds in one leaf from a pint to a quart; and although it must be of great use to the trees it grows on, to birds and other animals its use is even greater.

“When we find these pines,” says Dampier, the famous navigator, “we stick our knives into the leaves just above the root, and the water gushing out, we catch it in our hats, as I myself have frequently done to my great relief.”

Another tree, called the *Water-with*, in Jamaica, has similar uses: it is like a vine in size and shape,

and though growing in parched districts, is yet so full of clear sap or water, that by cutting a piece two or three yards long, and merely holding it to the mouth, a plentiful draught is obtained. In the East there is a plant somewhat of the same kind, called the *Bejuco*, which grows near other trees and twines round them, with its end hanging downwards, but so full of juice, that, on cutting it, a good stream of water spouts from it ; and this, not only by the stalk touching the tree so closely must refresh it, but affords a supply to animals, and to the weary herdsman on the mountains. Another plant, the *Nepenthes distillatoria*, is found in the same regions, with a yet more singular structure. It has natural mugs or tankards hanging from its leaves, and holding each from a pint to a quart of very pure water. Two singular provisions are to be marked in this vegetable. There grows over the mouth of the tankard, a leaf nearly its size and shape, like a lid or cover, which prevents evaporation from the sun's rays ; and the water that fills the tankard is perfectly sweet and clear, although the ground in which the plant grows is a marsh of the most muddy and unwholesome kind. The process of vegetation filtrates or distils the liquid, so as to produce from the worst, the purest water.\* The *Palo de Vaca*, or cow-tree, grows in South

\* A specimen of this curious plant, though of a small size, is to be found in the fine collection at Wentworth, reared by Mr. Cooper.



America, upon the most dry and rocky soil, and in a climate where for months not a drop of rain falls. On piercing the trunk, however, a sweet and nourishing milk is obtained, which the natives gladly receive in large bowls. If some plants thus furnish drink, where it might least be expected, others prepare, as it were, in the desert, the food of man in abundance. A single *Tapioca* tree is said to afford, from its pith, the whole sustenance of several men for a season.

#### V. ADVANTAGES AND PLEASURES OF SCIENCE.

AFTER the many instances or samples which have now been given of the nature and objects of Natural Science, we might proceed to a different field, and describe in the same way the other grand branch of human knowledge, that which teaches the properties or habits of *Mind*—the *intellectual faculties* of man, or the powers of his understanding, by which he perceives, imagines, remembers, and reasons;—his *moral faculties*, or the feelings and passions which influence him;—and, lastly, as a conclusion or result drawn from the whole, his *duties* both towards himself as an individual, and towards others as a member of society: which last head opens to our view the whole doctrines of *political science*, including the nature of govern-

*ments*, of *policy*, and generally of *laws*. But we shall abstain at present from entering at all upon this field, and shall now take up the subject more particularly pointed at through the course of the foregoing observations, and to illustrate which they have been framed, namely, — the Use and Pleasure of Scientific Studies.

Man is composed of two parts, body and mind, connected indeed together, but wholly different from one another. The nature of the union—the part of our outward and visible frame in which it is peculiarly formed—or whether the soul be indeed connected or not with any particular portion of the body, so as to reside there—are points as yet wholly hid from our knowledge, and which are likely to remain for ever concealed. But this we know, as certainly as we can know any truth, that there is such a thing as the *Mind*; and that we have at the least as good proof of its existence, independent of the Body, as we have of the existence of the Body itself. Each has its uses, and each has its peculiar gratifications. The bounty of Providence has given us outward senses to be employed, and has furnished the means of gratifying them in various kind, and in ample measure. As long as we only taste those pleasures according to the rules of prudence and of our duty, that is, in moderation for our own sakes, and in harmlessness towards our neighbours, we fulfil rather than

thwart the purpose of our being. But the same bountiful Providence has endowed us with the higher nature also—with understandings as well as with senses—with faculties that are of a more exalted order, and admit of more refined enjoyments, than any to which the bodily frame can minister ; and by pursuing such gratifications, rather than those of mere sense, we fulfil the most exalted ends of our creation, and obtain both a present and a future reward. These things are often said, but they are not therefore the less true, or the less worthy of deep attention. Let us mark their practical application to the occupations and enjoyments of all branches of society, beginning with those who form the great bulk of every community, the working classes, by what names soever their vocations may be called—professions, arts, trades, handicrafts, or common labour.

1. The first object of every man who has to depend upon his own exertions must needs be to provide for his daily wants. This is a high and important office ; it deserves his utmost attention ; it includes some of his most sacred duties, both to himself, his kindred, and his country ; and although, in performing this task, he is only influenced by a regard to his own interest, or by his necessities, yet it is an employment which renders him truly the best benefactor of the community he belongs to. All other pur-

suits must give way to this ; the hours which he devotes to learning must be after he has done his work ; his independence, without which he is not fit to be called a man, requires first of all that he should have insured for himself, and those dependent on him, a comfortable subsistence before he can have a right to taste any indulgence, either of his senses or of his mind ; and the more he learns—the greater progress he makes in the sciences—the more will he value that independence, and the more will he prize the industry, the habits of regular labour, whereby he is enabled to secure so prime a blessing.

In one view, it is true, the progress which he makes in science may help his ordinary exertions, the main business of every man's life. There is hardly any trade or occupation in which useful lessons may not be learnt by studying one science or another. The necessity of science to the more liberal professions is self-evident ; little less manifest is the use to their members of extending their knowledge beyond the branches of study with which their several pursuits are peculiarly conversant. But the other departments of industry derive hardly less benefit from the same source. To how many kinds of workmen must a knowledge of Mechanical Philosophy be useful ! To how many others does Chemistry prove almost necessary ! Every one must with a glance perceive



that to engineers, watch-makers, instrument-makers, bleachers, and dyers, those sciences are most useful, if not necessary. But carpenters and masons are surely likely to do their work better for knowing how to measure, which Practical Mathematics teaches them, and how to estimate the strength of timber, of walls, and of arches, which they learn from Practical Mechanics; and they who work in various metals are certain to be the more skilful in their trades for knowing the nature of those substances, and their relations to both heat and other metals, and to the airs and liquids they come in contact with. Nay, the farm servant, or day-labourer, whether in his master's employ, or tending the concerns of his own cottage, must derive great practical benefit,—must be both a better servant, and a more thrifty, and therefore comfortable, cottager, for knowing something of the nature of soils and manures, which Chemistry teaches, and something of the habits of animals, and the qualities and growth of plants, which he learns from Natural History and Chemistry together. In truth, though a man be neither mechanic nor peasant, but only one having a pot to boil, he is sure to learn from science lessons which will enable him to cook his morsel better, save his fuel, and both vary his dish and improve it. The art of good and cheap cookery is intimately connected with the principles of chemical philosophy, and has received

much, and will yet receive more, improvement from their application. Nor is it enough to say, that philosophers may discover all that is wanted, and may invent practical methods, which it is sufficient for the working man to learn by rote without knowing the principles. He never will work so well if he is ignorant of the principles; and for a plain reason:—if he only learn his lesson by rote, the least change of circumstances puts him out. Be the method ever so general, cases will always arise in which it must be varied in order to apply; and if the workman only knows the rule without knowing the reason, he must be at fault the moment he is required to make any new application it. This, then, is the *first* use of learning the principles of science: it makes men more skilful, expert, and useful in the particular kinds of work by which they are to earn their bread, and by which they are to make it go far and taste well when earned.

2. But another use of such knowledge to handicraftsmen is equally obvious: it gives every man a chance, according to his natural talents, of becoming an improver of the art he works at, and even a discoverer in the sciences connected with it. He is daily handling the tools and materials with which new experiments are to be made; and daily witnessing the operations of nature, whether in the motions and pressures of bodies, or in their chemi-

cal actions on each other. All opportunities of making experiments must be unimproved, all appearances must pass unobserved, if he has no knowledge of the principles ; but with this knowledge he is more likely than another person to strike out something new which may be useful in art, or curious or interesting in science. Very few great discoveries have been made by chance and by ignorant persons, much fewer than is generally supposed. It is commonly told of the steam-engine, that an idle boy being employed to stop and open a valve, saw that he could save himself the trouble of attending and watching it, by fixing a plug upon a part of the machine which came to the place at the proper times, in consequence of the general movement. This is possible, no doubt ; though nothing very certain is known respecting the origin of the story ; but improvements of any value are very seldom indeed so easily found out, and hardly another instance can be named of important discoveries so purely accidental. They are generally made by persons of competent knowledge, and who are in search of them. The improvements of the Steam-engine by Watt resulted from the most learned investigation of mathematical, mechanical, and chemical truths. Arkwright devoted many years, five at the least, to his invention of spinning-jennies, and he was a man perfectly conversant in everything that relates to the construction of

machinery : he had minutely examined it, and knew the effects of each part, though he had not received any thing like a scientific education. If he had, we should in all probability have been indebted to him for scientific discoveries as well as practical improvements. The most beautiful and useful invention of late times, the Safety-lamp, was the reward of a series of philosophical experiments made by one thoroughly skilled in every branch of chemical science. The new process of Refining Sugar, by which more money has been made in a shorter time, and with less risk and trouble, than was ever perhaps gained from an invention, was discovered by a most accomplished chemist,\* and was the fruit of a long course of experiments, in the progress of which, known philosophical principles were constantly applied, and one or two new principles ascertained. But in so far as chance has anything to do with discovery, surely it is worth the while of those who are constantly working in particular employments to obtain the knowledge required, because their chances are greater than other people's of so applying that knowledge as to hit upon new and useful ideas : they are always in the way of perceiving what is wanting, or what is amiss in the old methods ; and they have a better chance of making the improvements. In a word, to use a common expression, they are in the way of good

\* Edward Howard, brother of the Duke of Norfolk.



luck ; and if they possess the requisite information, they can take advantage of it when it comes to them. This, then, is the *second* great use of learning the sciences : it enables men to make improvements in the arts, and discoveries in philosophy, which may directly benefit themselves and mankind.

3. Now, these are the *practical* advantages of learning ; but the *third* benefit is, when rightly considered, just as practical as the other two—the pleasure derived from mere knowledge, without any view to our own bodily enjoyments : and this applies to all classes, the idle as well as the industrious, if, indeed, it be not peculiarly applicable to those who enjoy the inestimable blessing of having time at their command. Every man is by nature endowed with the power of gaining knowledge ; and the taste for it, the capacity to be pleased with it, forms equally a part of the natural constitution of his mind. It is his own fault, or the fault of his education, if he derives no gratification from it. There is a satisfaction in knowing what others know—in not being more ignorant than those we live with : there is a satisfaction in knowing what others do not know—in being more informed than they are. But this is quite independent of the pure pleasure of knowledge—of gratifying a curiosity implanted in us by Providence, to lead us towards the better understanding of the universe in which our lot is cast,

and the nature wherewithal we are clothed. That every man is capable of being delighted with extending his information upon matters of science will be evident from a few plain considerations.

Reflect how many parts of the reading, even of persons ignorant of all sciences, refer to matters wholly unconnected with any interest or advantage to be derived from the knowledge acquired. Every one is amused with reading a story : a romance may divert some, and a fairy tale may entertain others ; but no benefit beyond the amusement is derived from this source : the imagination is gratified ; and we willingly spend a good deal of time and a little money in this gratification. rather than in resting after fatigue, or in any other bodily indulgence. So we read a newspaper, without any view to the advantage we are to gain from learning the news, but because it interests and amuses us to know what is passing. One object, no doubt, is to become acquainted with matters relating to the welfare of the country ; but we also read the occurrences which do little or not at all regard the public interests, and we take a pleasure in reading them. Accidents, adventures, anecdotes, crimes, and a variety of other things amuse us, independent of the information respecting public affairs, in which we feel interested as citizens of the state, or as members of a particular body. It is of little importance to inquire how and why these things excite our atten-

tion, and wherefore the reading about them is a pleasure; the fact is certain; and it proves clearly that there is a positive enjoyment in knowing what we did not know before; and this pleasure is greatly increased when the information is such as excites our surprise, wonder, or admiration. Most persons who take delight in reading tales of ghosts, which they know to be false, and feel all the while to be silly in the extreme, are merely gratified, or rather occupied with the strong emotions of horror excited by the momentary belief, for it can only last an instant. Such reading is a degrading waste of precious time, and has even a bad effect upon the feelings and the judgment.\* But true stories of horrid crimes, as murders, and pitiable misfortunes, as shipwrecks, are not much more instructive. It may be better to read these than to sit yawning and idle—much better than to sit drinking or gaming, which, when carried to the least excess, are crimes in themselves, and the fruitful parents of many more. But this is nearly as much as can be said for such vain and unprofitable reading. If it be a

\* *Children's books* have at all times been made upon the pernicious plan of exciting wonder, generally horror, at whatever risk. The folly and misery occasioned by this error, it would be difficult to estimate. The time may come when it will be felt and understood. At present, the inveterate habits of parents and nurses prevent the children from benefiting by the excellent lessons of Mrs. Barbauld and Miss Edgeworth.

pleasure to gratify curiosity, to know what we were ignorant of, to have our feelings of wonder called forth, how pure a delight of this very kind does Natural Science hold out to its students ! Recollect some of the extraordinary discoveries of Mechanical Philosophy. How wonderful are the laws that regulate the motions of fluids ! Is there anything in all the idle books of tales and horrors more truly astonishing than the fact, that a few pounds of water may, by mere pressure, without any machinery—by merely being placed in a particular way, produce an irresistible force ? What can be more strange, than that an ounce weight should balance hundreds of pounds, by the intervention of a few bars of thin iron ? Observe the extraordinary truths which Optical Science discloses. Can any thing surprise us more, than to find that the colour of white is a mixture of all others—that red, and blue, and green, and all the rest, merely by being blended in certain proportions, form what we had fancied rather to be no colour at all, than all colours together ? Chemistry is not behind in its wonders. That the diamond should be made of the same material with coal ; that water should be chiefly composed of an inflammable substance ; that acids should be, for the most part, formed of different kinds of air, and that one of those acids, whose strength can dissolve almost any of the metals, should consist of the self-same ingredients



with the common air we breathe ; that salts should be of a metallic nature, and composed, in great part, of metals, fluid like quicksilver, but lighter than water, and which, without any heating, take fire upon being exposed to the air, and by burning, form the substance so abounding in saltpetre and in the ashes of burnt wood : these, surely, are things to excite the wonder of any reflecting mind—nay, of any one but little accustomed to reflect. And yet these are trifling when compared to the prodigies which Astronomy opens to our view : the enormous masses of the heavenly bodies ; their immense distances ; their countless numbers, and their motions, whose swiftness mocks the uttermost efforts of the imagination.

Akin to this pleasure of contemplating new and extraordinary truths, is the gratification of a more learned curiosity, by tracing resemblances and relations between things, which, to common apprehension, seem widely different. Mathematical science to thinking minds affords this pleasure in a high degree. It is agreeable to know that the three angles of every triangle, whatever be its size, howsoever its sides may be inclined to each other, are always, of necessity, when taken together, the same in amount : that any regular kind of figure whatever, upon the one side of a right-angled triangle, is equal to the two figures of the same kind upon the two other sides, whatever be the size

of the triangle: that the properties of an oval curve are extremely similar to those of a curve which appears the least like it of any, consisting of two branches of infinite extent, with their backs turned to each other. To trace such unexpected resemblances is, indeed, the object of all philosophy; and experimental science, in particular, is occupied with such investigations, giving us general views, and enabling us to explain the appearances of nature, that is, to show how one appearance is connected with another. But we are now considering only the gratification derived from learning these things. It is surely a satisfaction, for instance, to know that the same thing, or motion, or whatever it is, which causes the sensation of heat, causes also fluidity, and expands bodies in all directions; that electricity, the light which is seen on the back of a cat when slightly rubbed on a frosty evening, is the very same matter with the lightning of the clouds;—that plants breathe like ourselves, but differently by day and by night;—that the air which burns in our lamps enables a balloon to mount, and causes the globules of the dust of plants to rise, float through the air, and continue their race—in a word, is the immediate cause of vegetation. Nothing can at first view appear less like, or less likely to be caused by the same thing, than the processes of burning and of breathing,—the rust of metals and burning,—an acid and rust,—the influence

of a plant on the air it grows in by night, and of an animal on the same air at any time, nay, and of a body burning in that air; and yet all these are the same operation. It is an undeniable fact, that the very same thing which makes the fire burn, makes metals rust, forms acids, and enables plants and animals to breathe; that these operations, so unlike to common eyes, when examined by the light of science are the same,—the rusting of metals,—the formation of acids,—the burning of inflammable bodies,—the breathing of animals,—and the growth of plants by night. To know this is a positive gratification. Is it not pleasing to find the same substance in various situations extremely unlike each other;—to meet with fixed air as the produce of burning, of breathing, and of vegetation;—to find that it is the choke-damp of mines, the bad air in the grotto at Naples, the cause of death in neglecting brewers' vats, and of the brisk and acid flavour of Seltzer and other mineral springs? Nothing can be less like than the working of a vast steam-engine, of the old construction, and the crawling of a fly upon the window. Yet we find that these two operations are performed by the same means, the weight of the atmosphere, and that a sea-horse climbs the ice-hills by no other power. Can anything be more strange to contemplate? Is there in all the fairy-tales that ever were fancied anything more calculated to arrest the attention and to oc-

cupy and to gratify the mind, than this most unexpected resemblance between things so unlike to the eyes of ordinary beholders? What more pleasing occupation than to see uncovered and bared before our eyes the very instrument and the process by which Nature works? Then we raise our views to the structure of the heavens; and are again gratified with tracing accurate but most unexpected resemblances. Is it not in the highest degree interesting to find, that the power which keeps this earth in its shape, and in its path, wheeling upon its axis and round the sun, extends over all the other worlds that compose the universe, and gives to each its proper place and motion; that this same power keeps the moon in her path round our earth, and our earth in its path round the sun, and each planet in its path; that the same power causes the tides upon our globe, and the peculiar form of the globe itself; and that, after all, it is the same power which makes a stone fall to the ground? To learn these things, and to reflect upon them, occupies the faculties, fills the mind, and produces certain as well as pure gratification.

But if the knowledge of the doctrines unfolded by science is pleasing, so is the being able to trace the steps by which those doctrines are investigated, and their truth demonstrated: indeed you cannot be said, in any sense of the word, to have learnt them, or to know them, if you have not so studied



them as to perceive how they are proved. Without this you never can expect to remember them long, or to understand them accurately; and that would of itself be reason enough for examining closely the grounds they rest on. But there is the highest gratification of all, in being able to see distinctly those grounds, so as to be satisfied that a belief in the doctrines is well founded. Hence to follow a demonstration of a grand mathematical truth—to perceive how clearly and how inevitably one step succeeds another, and how the whole steps lead to the conclusion—to observe how certainly and unerringly the reasoning goes on from things perfectly self-evident, and by the smallest addition at each step, every one being as easily taken after the one before, as the first step of all was, and yet the result being something not only far from self-evident, but so general and strange, that you can hardly believe it to be true, and are only convinced of it by going over the whole reasoning—this operation of the understanding, to those who so exercise themselves, always affords the highest delight. The contemplation of experimental inquiries, and the examination of reasoning founded upon the facts which our experiments and observations disclose, is another fruitful source of enjoyment, and no other means can be devised for either imprinting the results upon our memory, or enabling us really to enjoy the whole pleasures of science. They who

found the study of some branches dry and tedious at the first, have generally become more and more interested as they went on; each difficulty overcome gives an additional relish to the pursuit, and makes us feel, as it were, that we have by our work and labour established a right of property in the subject. Let any man pass an evening in vacant idleness, or even in reading some silly tale, and compare the state of his mind when he goes to sleep or gets up next morning with its state some other day when he has passed a few hours in going through the proofs, by facts and reasoning, of some of the great doctrines in Natural Science, learning truths wholly new to him, and satisfying himself by careful examination of the grounds on which known truths rest, so as to be not only acquainted with the doctrines themselves, but able to show why he believes them, and to prove before others that they are true;—he will find as great a difference as can exist in the same being,—the difference between looking back upon time unprofitably wasted, and time spent in self-improvement: he will feel himself in the one case listless and dissatisfied, in the other comfortable and happy: in the one case, if he do not appear to himself humbled, at least he will not have earned any claim to his own respect; in the other case, he will enjoy a proud consciousness of having, by his own exertions, become a wiser and therefore a more exalted creature.

To pass our time in the study of the sciences, in learning what others have discovered, and in extending the bounds of human knowledge, has, in all ages, been reckoned the most dignified and happy of human occupations; and the name of Philosopher, or Lover of Wisdom, is given to those who lead such a life. But it is by no means necessary that a man should do nothing else than study known truths, and explore new, in order to earn this high title. Some of the greatest philosophers, in all ages, have been engaged in the pursuits of active life; and an assiduous devotion of the bulk of our time to the work which our condition requires, is an important duty, and indicates the possession of practical wisdom. This, however, does by no means hinder us from applying the rest of our time, beside what nature requires for meals and rest, to the study of science; and he who, in whatever station his lot may be cast, works his day's work, and improves his mind in the evening, as well as he who, placed above such necessity, prefers the refined and elevating pleasures of knowledge to the low gratification of the senses, richly deserves the name of a True Philosopher.

One of the most delightful treats which science affords us is the knowledge of the extraordinary powers with which the human mind is endowed. No man, until he has studied philosophy, can have a just idea of the great things for which Providence

has fitted his understanding—the extraordinary disproportion which there is between his natural strength and the powers of his mind and the force he derives from them. When we survey the marvellous truths of Astronomy, we are first of all lost in the feeling of immense space, and of the comparative insignificance of this globe and its inhabitants. But there soon arises a sense of gratification and of new wonder at perceiving how so insignificant a creature has been able to reach such a knowledge of the unbounded system of the universe—to penetrate, as it were, through all spaces and become familiar with the laws of nature at distances so enormous as to baffle our imagination—to be able to say, not merely that the Sun has 329,630 times the quantity of matter which our globe has, Jupiter  $308\frac{9}{10}$ , and Saturn  $93\frac{1}{2}$  times; but that a pound of lead weighs at the Sun 22 lbs. 15 ozs. 16 dwts. 8 grs. and  $\frac{3}{4}$  of a grain! at Jupiter 2 lbs. 1 oz. 19 dwts. 1 gr.  $\frac{2}{3}$ ; and at Saturn 1 lb. 3 ozs. 8 dwts. 20 grs.  $\frac{1}{11}$  part of a grain! And what is far more wonderful, to discover the laws by which the whole of this vast system is held together and maintained through countless ages in perfect security and order. It is surely no mean reward of our labour to become acquainted with the prodigious genius of those who have almost exalted the nature of man above its destined sphere; when, admitted to a fellowship with these loftier



minds, we discover how it comes to pass that, by universal consent, they hold a station apart, rising over all the Great Teachers of mankind, and spoken of reverently, as if NEWTON and LAPLACE were not the names of mortal men.

The highest of all our gratifications in the contemplations of science remains : we are raised by them to an understanding of the infinite wisdom and goodness which the Creator has displayed in his works. Not a step can we take in any direction without perceiving the most extraordinary traces of design ; and the skill everywhere conspicuous is calculated, in so vast a proportion of instances, to promote the happiness of living creatures, and especially of our own kind, that we can feel no hesitation in concluding that, if we knew the whole scheme of Providence, every part would be found in harmony with a plan of absolute benevolence. Independently, however, of this most consoling inference, the delight is inexpressible of being able to follow, as it were, with our eyes, the marvellous works of the Great Architect of Nature—to trace the unbounded power and exquisite skill which are exhibited in the most minute, as well as the mightiest parts of his system. The pleasure derived from this study is unceasing, and so various, that it never tires the appetite. But it is unlike the low gratifications of sense in another respect : while those hurt the health, debase the understand-

ing, and corrupt the feelings, this elevates and refines our nature, teaching us to look upon all earthly objects as insignificant, and below our notice, except the pursuit of knowledge and the cultivation of virtue; and giving a dignity and importance to the enjoyment of life, which the frivolous and the grovelling cannot even comprehend.

Let us, then, conclude, that the Pleasures of Science go hand in hand with the solid benefits derived from it; that they tend, unlike other gratifications, not only to make our lives more agreeable, but better; and that a rational being is bound by every motive of interest and of duty, to direct his mind towards pursuits which are found to be the sure path of Virtue as well as of Happiness.

---

## OBJECTS,

## PLEASURES, AND ADVANTAGES

OF

POLITICAL SCIENCE.

1840

1841

1842

1843

1844

1845



## OBJECTS, &c.

---

THE Sciences which form the subject of our most useful study, and which, next to the cultivation of religion and the practice of virtue, are the source of our purest enjoyments in this world, may be divided into three great classes or branches, according to their several objects. Those objects are—the Relations of Abstract Ideas—the Properties of Matter—the Qualities of Mind. All the subjects of scientific research may be classed under one or other of these three heads; and all the sciences may, accordingly, be ranged under one or other branch of a corresponding threefold division.

To the first branch belong the abstract ideas of quantity—that is, of space in its different forms and portions; and of these the science of Geometry treats;—the abstract ideas of number, which form the subject of Arithmetic, general or particular, the one called Algebra, the other Common Arithmetic, the comparison and classification of all ideas, generally, whether abstract or not, and whether relating to matter or mind; and this forms

the subject of Logic, or the science of reasoning and classification.

The first branch deals with mere abstract ideas, and has no necessary reference to actual existences; these form the subjects of the other two, which, accordingly, do not, like the former, rest wholly upon reasoning, but depend upon experience also. The one branch relating to matter, its properties and motions, is termed Physics,\* or Natural Philosophy; the other, relating to the nature and affections of the mind, is termed Metaphysics or Psychology,† or Moral or Mental Philosophy.

Physical or Natural Philosophy is subdivided into various branches: one, for example, treating of weight and motion, is called Dynamics, or Mechanics and Statics; another, treating of the heavenly bodies, is termed Astronomy; another, of light, is termed Optics; another, of the qualities and composition of substances, called Chemistry; another, of the properties of living bodies, called Anatomy and Physiology; another, of the classification of substances and animals, called Natural History. To all of these accurate observation and experiment may be applied, and to some of them mathematical principles, by which extraordinary

\* From the Greek word signifying natural objects or qualities.

† From the Greek word signifying to discourse of the soul or mind.

progress has been made in extending our knowledge of the laws of nature.

Moral or Mental Philosophy consists of two great subdivisions: one treating of the powers, faculties, and affections of the mind—that is, its intellectual as well as its moral or active powers—the faculties of the understanding and those of the will, or our appetites and feelings as well as our intellects—and this branch treats of all spiritual existences, from the Great First Cause, the Creator and Preserver of the universe, to the mind of man and his habits, and down to the faculties and the instincts of the lower animals. This division is sometimes called Psychology, when that phrase is not used for the whole of moral science. The other subdivision treats of our duties towards the Deity and towards our fellow-creatures, and is generally termed Ethics.\* But perhaps the better and more correct division of the whole of Moral Philosophy is to consider it in two points of view—as it treats of man in his individual capacity; and man as a member of society. This last branch is termed Political† Science, and forms the subject of the following Discourse.

We have already adverted to one important cir-

\* From the Greek for morals.

† From the Greek for city or state—the different communities in Greece having originally been cities and their adjoining territories.

cumstance which distinguishes both the two branches of science which treat of actual existences from those which treat of abstract ideas and their relations. The truths of both Natural and Moral Philosophy differ from those of abstract science in this important particular, that they partly depend on experience and not exclusively on reasoning; they are contingent, and not necessary; the world, moral and material, might have been so constructed as to render untrue all things now known to be true respecting it; whereas the truths of abstract science, arithmetic for example, are independent of all contingencies, and do not result from any experience, and could not possibly have been different from what they are. It is easy to conceive a world in which bodies should attract each other by a wholly different law from that of gravitation; but we cannot form to ourselves the idea of any state of things in which two and two should not be equal to four, nor the three angles of a triangle equal to two right angles. It follows that, in the sciences both of matter and of mind, we must be content with evidence of an inferior kind to that which the mathematical sciences employ; and resting satisfied with as high a degree of probability as we can attain, must draw our practical conclusions with the hesitation which such a liability to error naturally prescribes.

The first, or abstract branch, is capable of appli-



cation to the other two. The precision with which the qualities and the functions of matter are observable, and the ease with which these may be subjected to experiment, enable us to investigate them with great facility, and to draw our general conclusions with much certainty. But this power is greatly increased by the use of mathematical principles, which enable us to deduce general inferences from observed facts, the truth of which facts being admitted, those inferences follow as absolute and necessary, and not as matter of contingent truth. Thus the observations of astronomers show certain appearances of the heavenly bodies; the observations of mechanicians show certain things respecting falling bodies on our globe. But suppose the truth of such observations to be admitted, mathematical reasoning shows, without the possibility of error or of doubt, that the power of gravitation extends to the heavens, and that the planets wheel round the sun as their centre by the same power which makes a stone fall to the ground if unsupported. This inference is a certain and necessary truth, if the facts be true which our observation teaches; and such a mixture of necessary with contingent truths, forms a very large portion of Physics, or Natural Philosophy. But it is only in a few cases that we can obtain the aid of mathematical reasoning to render our inferences certain and necessary from facts observed in the science of

mind, as it is also comparatively few observations and experiments that we are enabled to make upon its qualities. Hence there is a far less degree of certainty in this than we can attain in the physical sciences, and hence we ought to be doubly on our guard against dogmatism and intolerance of other men's opinions in all the departments of this less exact philosophy. The controversies which have oftentimes arisen among metaphysicians, strongly illustrate how little the positive dogmatism and exclusive intolerance of men holding one class of opinions towards those who held another, was in proportion to the degree of evidence upon which their inquiries proceeded. Mathematicians who run hardly any risk of error—naturalists who run but little more—have never been so bigoted and so uncharitable as those whose speculations are fated to be always involved in more or less of doubt; and when we come to political reasoners, we find, beside the intolerance of metaphysicians, a new source of error and of fault in the excitement which the interests of men, real or supposed, lend to their passions.

It would, however, be an equally groundless and a very pernicious error to run from the extreme of dogmatism into the extreme of scepticism, and to suppose that because the evidence upon which our conclusions in moral science rest is inferior to the proofs of mathematical, and even of physical truth,

therefore we cannot trust the deductions of ethical principles, or their applications to the affairs of men as members of political communities. The more nice and subtle points of metaphysical philosophy are those upon which the chief doubts prevail. Some portions of psychology are placed above the reach of the human faculties, as indeed are some of the more intimate qualities of matter; and it is eminently improbable that we shall ever be able to ascertain the essential nature of mind; but so no more are we ever likely to ascertain the ultimate cause of gravitation, or to penetrate into the laws which govern the primary combinations of material particles. Still, the more important, because the more practical, subjects of our inquiries into the nature of the human mind, the laws which govern man's habits as an individual, and the principles of human action upon which the structure of society and its movements depend, are not placed on such unapproachable heights. Within certain limits, safe conclusions can be drawn respecting these important matters. Facts may be observed, collected, and generalized, not, certainly, with the perfect accuracy which can be attained in the inductions of physical science, yet still with sufficient correctness to form the groundwork of safe practical inferences. General principles of Moral and Political Science may thus be established, by reasoning upon the results of experience; and from those principles,

rules for our guidance may be drawn, highly useful both in the regulation of the individual understanding, and in managing the concerns of communities of men. To deny that Morals and Politics may be reduced to a science, because the truths of Natural Philosophy rest upon more clear evidence and assume a more precise form, would be as absurd as to deny that experimental science is deserving of the name, because its proofs are more feeble, and its propositions less definite and less closely connected together than those of pure mathematics.

But it is more especially with Political Philosophy that we have now to do; and there are many reasons why its truths should be better capable of clear demonstration and of distinct statement than those of the other branches of Moral or Ethical Science.

1. In the first place, although each individual by his consciousness is continually in a situation that enables him to make observations on the human faculties by attending to the operations of his own mind, yet we know that hardly any habit is later acquired by the few who ever learn it at all, than the habit of turning the observation inwards, and making the mind the subject of its own contemplations. It is a process, indeed, which not one person in a hundred thousand ever thinks of undertaking. But the bulk of mankind are political observers. The operations of government, the habits and pro-



ceedings of the people, the conduct of communities, their fortunes and their fate, form the daily subject of reflection with all persons even of an ordinary degree of intelligence in every civilized country, and do not escape the observation of the bulk of the people, even in communities subject to such restraints from the structure of their governments, as to render the open discussion of such matters hardly possible in any class of society. Hence the observation of facts on political subjects is performed almost universally at all times, whether these facts are collected and classified or not.

2. It follows, in the next place, that the appetite for knowledge of this description is far more generally diffused than for either moral or ethical knowledge; that numberless bodies of men in every country conceive themselves interested in political subjects, who would regard metaphysical speculations as wholly foreign to their concerns; and that there prevails everywhere a strong desire for such information, unless in places where misgovernment may have actually reduced the minds of the community to a state bordering upon the dulness and insensibility of the brute creation.

3. Thirdly. The facts on which Political Science rests are more plain, manifest, and tangible, than those which form the subject of Moral Philosophy in its other branches. Those facts are more obvious; they are perceptible in most cases to the senses;

they are reducible to number and measure. The accumulation or diminution of public wealth,—the prosperity or suffering of the people,—the progress of population,—the quiet or disturbed state of a country,—the prevalence of one portion or order of a state over the others,—the effect of a particular form of government,—the changes consequent upon its altered structure; all these are matters of distinct observation, and most of them subject to exact calculation. But these, and such as these, are the facts upon which the doctrines of Political Science are grounded, and these doctrines are the results of reasoning upon such facts.

4. Fourthly. The mere facts themselves connected with political science are far more important and far more interesting than those on which the other branches of moral philosophy rest. The peculiar action of the intellectual faculties, or of the feelings and passions, is not a subject of great extent. All we know of it is soon told, and there is but little variety in different individuals as far as it is concerned. Different characters may be described, and the history of individuals affords great entertainment, as well as the matter of much interesting reflection; but unless their actions are also comprehended in the narrative, the interest flags, and the story can scarcely go on; and those actions almost always come within the province of Political Science. The intellectual or moral habits

of men as individuals, apart from their conduct, form a small and not an extremely interesting chapter in the history of man. But how different are those facts with which the political observer is concerned ! The mere history of national affairs—the narrative of those public events which take place—the changes in the condition and fortunes of whole communities—their relations with each other, whether in peace or war—the rise and decay of great institutions affecting the welfare of millions—the progress of a policy upon which the happiness, nay, the very existence of whole nations depends—the varieties in the governments under which they live—the influence of those Governments upon the condition of the people—the effects which they produce upon their intercourse with other countries,—all these are subjects of most interesting contemplation in themselves, as mere facts, wholly independent of any general views to which they may lead, or of any practical conclusions which may be derived from them.

Mr. Hume has written an ingenious and a sound dissertation, to prove that Politics—meaning the branch which treats of the structure of governments—may be reduced to a science ; and he illustrates this by deducing from Political History certain general principles which must at all times and in all circumstances hold true. But whether he be right or not, even if there were no means of drawing such strictly and universally true inferences, at

least the importance of the facts which the political reasoner deals with must be confessed, and the great interest which attaches to the mere knowledge of those facts cannot be doubted.

5. Lastly. We may observe that, the facts in question being of a public nature, and so known to the world at large, a better security is afforded for their being accurately observed and truly recorded. History, statistics, the narrative of public events, the details of national affairs,—these are the sources from which the political reasoner draws his facts. Established institutions, bodies of law, universally known customs, wars, treaties, the manifest state of the world in its various regions at different times, these are the facts upon which the political philosopher reasons, which he generalizes, from which he draws his conclusions, on which he builds his systems. But we shall be the better able to appreciate the peculiar excellence of this study if we now take a survey of the science itself, and thus present, as it were, a map of it to the eye, with the natural limits and boundaries of the various provinces into which it is divided.

The great family of mankind dispersed over the earth occupy its various portions in various bodies or communities, each bound together by certain ties, and bearing in those portions a general resemblance to, or having distinctive features in which they differ from, the rest. These communities differ in their customs, character, and



institutions ; in their general circumstances and degree of civilization. The nature of their institutions,—of the various establishments for public purposes which exist for the management of their common affairs,—of the regimen under which and the rules by which the members of each community, whether compelled by force, or agreeing voluntarily, continue to live ;—in a word, the Domestic Management of each state—forms the subject of the first great branch or province of Political Science. The second relates to the intercourse of different communities with each other ; the mutual relations of the different communities ; the principles or rules established for their demeanour towards one another ;—in a word, the external affairs of each state, but the national concerns of the whole considered as one general community, the members of which are not individuals but separate states. The former province is called Domestic Policy—the latter, Foreign or International Policy.

Domestic Policy is subdivided into two branches.

Each community must be subject to some kind of rule, or regimen, or government ; some force established for restraining the excesses of individuals, for preventing wrongs and creating and protecting rights, and for superintending those things which are necessary to the public security and conducive to the public benefit, but which, if left to individuals, never could be accomplished

at all, and finally, for representing the community in its intercourse with other states. The nature of this rule or government differs in different countries from the accidents of events, and from the peculiarities of natural situation and of national character. The different forms of government,—the distribution in each state of the power by which its people are ruled,—the arrangements which result from these diversities,—their influence upon the security, improvement, comfort, and happiness of the people in each—are the facts from which the principles must be drawn which constitute the Science of Government.

This science, then, forming the first great subdivision of Domestic and National Polity, treats of two important matters,—first, the Principles relating to the establishment of all Government generally, and on which the establishment of the social relation, the formation of any connection between the ruler and the people, depends; and, secondly, the principles relating to the distribution of power in different states,—in other words, the different Constitutions or Forms of Government in different countries.

But there is another great subdivision of Domestic Polity, not inferior in importance to the former, and, although intimately connected with it, yet easily distinguishable from it. The manner in which men manage their private concerns,—the

course they pursue in their dealings with each other,—their way of exerting their industry for their subsistence, or comfort, or indulgence,—these proceedings may take place independent of the form of government under which they live; and, indeed, as no ruler has anything to do with them, if each government did its duty, these proceedings would go on nearly in the same way under all governments, and only be affected incidentally by the difference in the form of each. Although, therefore, the interference of governments directly, and their influence indirectly, may affect men's conduct of their own affairs, still the principles which regulate that conduct, and the effects resulting from it, form a subject of consideration evidently distinguishable from that of government. This subject, then, relates to the wealth, the population, the education, of the people; and the conduct of the government, in respect to these particulars, forms an important part of the discussion. This branch of the subject is termed Economics, or Political Economy, because it relates to the management of a nation's domestic affairs as private economy does to the affairs of a family. The most important subject of Political Economy is the accumulation and distribution of wealth in all its branches, including foreign and colonial as well as domestic commerce. But it also treats of the principles which regulate the maintenance, increase, or

diminution of population,—the religious and civil education of the people,—the provisions necessary for securing the due administration of justice, civil and criminal, and, as subservient to these, the maintenance of police—the measures required for supporting the public expenditure or the financial system—the precautions necessary for the public defence or the military system—and generally all institutions, whether supported by private exertions or by the state, the objects of which are of a public nature.\*

Intimately connected with Political Economy and, indeed, running as it were through all its subdivisions, is Political Arithmetic, or the application of figures to the various subjects of which Political Economy treats,—as the details of public wealth, commerce, education, finance, population, civil and military establishments, all of which may be made more or less the subject of calculation from given facts. Statistics, or the record of all the facts relating to the actual situation of different countries, in these several respects is, properly speaking, a branch of Political Arithmetic.

The function of making those laws which are

\* These subjects may be separated from Political Economy and treated under the head of Functions of Government; they come under what the French call *le Droit Administratif*.



required from time to time for the government of a community, is vested in the supreme power of the State ; and the important office of Legislation, accordingly, is variously performed in different countries according to the different constitutions of each. In all States a great portion of the law is derived from custom, handed down by tradition and acted upon in practice, through a succession of ages. This is called Common or Unwritten Law, as contradistinguished from Statute or Written Law ; and though some nations have from time to time reduced to writing the provisions of the Common Law, thus furnishing themselves with Codes which comprehended all their laws, yet in all Systems of Law the distinctions between the two species may be traced ; and even where a Code exists, it is known what portions of it were once Customary or Common Law, because the other, or Statutory enactments, are known to have been first introduced at a particular time, whereas the Common Law had been used before it was reduced into writing. The different laws of each State range themselves under the various heads to which they belong, those heads being the different subdivisions of the two great branches of Domestic Policy—the Political and Economical—already referred to. But there are certain general principles of Legislation which are of universal application, just as there are certain principles relating to Govern-

ment, and certain principles relating to Economics, which are general, and do not depend upon the particular institutions established, or the particular systems adopted in different countries. The science of Jurisprudence treats of those general principles, and may be reckoned an appendix, but a most important one, to the branch of Domestic Policy.

The other main branch of Political Science considers nations as individuals forming a portion of a larger community—a community of nations; and treats of the principles which ought to govern them in their mutual intercourse. Those views which form the foundation of this science of Foreign or International Policy, are evidently, from their nature, a refinement introduced in a late period of society, because those views assume that communities, each of which is supreme and can have no superior on earth, are willing to regard themselves as subject to certain rules in their intercourse with other nations,—rules which no common chief can enforce, but the observance of which is rendered expedient by the interests of all, and which, therefore, are generally regarded as binding.

These rules are either those of sound policy or those of strict justice. The former class presents certain maxims as useful in regulating the conduct of nations towards each other, in order to provide for the general security, by preventing any one from becoming too powerful, and thus dangerous to

the independence of the others. The latter class acknowledges certain rights as belonging to each community, and denounces the infraction of these rights as a public wrong, giving the injured party a title to seek redress by force. Thus this Second Branch of political science consists of two subdivisions,—the one treats of the principles of *policy* which should guide nations in their mutual intercourse of peace and war, in the negotiation of treaties, the formation of alliances offensive and defensive, the combination of weak States to resist a stronger one, the precautions necessary for preventing too great acquisition of strength by any one State to the derangement of what is termed the general Balance of Power. These principles form the subject of Foreign Policy. The other subdivision treats of the *rights* of nations,—those rights in peace and war which are by common consent admitted to belong to each, because the common interests of humanity, the prevention of war, and the mitigation of its evils when it does occur, require some such general understanding and consent; and the rules relating to this second subdivision are called the Law of Nations or International Law—of which the true description is, that it forms the code by which the great community of nations are governed, or ought to be governed, in their conduct towards each other, as Municipal Law is the code by which the individual

members of any particular community are governed in their intercourse with one another. It is a very common error to confound with this branch of law many of the general principles of jurisprudence applicable to all nations, and to term these a portion of the Law of Nations.\*

It is obvious that of all sciences which form the subject of human study, none is calculated to afford greater pleasure, and few so great to the student, as the important one of which we have just been describing the nature and the subdivisions. In common with the different branches of Natural Philosophy, it possesses all the interest derived from the contemplation of important truths, the first and the purest of the pleasures derived from any department of science. There is a positive pleasure in that exercise of the mental faculties which the investigation of mathematical and physical truth affords. The contemplation of mathematical and physical truths is, in itself, always pleasing and wholesome to the mind. There is a real pleasure in tracing the relations between

\* In the following series the subject of Jurisprudence and International Law will be only treated incidentally, as the other matters to which they relate require, and not under separate heads. The same may be said of the other division of the second branch, namely, Foreign Policy, a conduct prescribed to nations by their mutual interests in their mutual intercourse.



figures and between substances, the resemblances unexpectedly found to exist among those which seem to differ, the precise differences found to exist between one figure and another, or one body and another. Thus, to find that the sum of the angles of all triangles, be their size or their form what it may, is uniformly the same, or that all circles, from the sun down to a watch-dial, are to each other in one fixed proportion, as the squares of their diameters, is a matter of pleasing contemplation which we are glad to learn and to remember from the very constitution of our minds. So there is a great, even an exquisite pleasure in learning the composition of bodies, in knowing, for instance, that water, once believed to be a simple element, is composed of the more considerable of two substances, which make, when united with heat in a certain form, the air we burn and the air we breathe; that rust is the combination of this last substance with metals; that flame is supported by it; that respiration is performed by means of it; that rusting, breathing, and burning, are all processes of the same kind; that two of the alkaline salts are themselves rusts of metals, one of these metals being lighter than water, burning spontaneously when exposed to the air, without any heat, and forming the salt by its combination. To know these things, and to contemplate such relations between bodies or operations seemingly so unlike, is in a high

degree delightful, even if no practical use could be made of such knowledge. So the sublime truths of astronomy afford extensive gratification to the student. To find that the planets and the comets which wheel round the sun with a swiftness immensely greater than that of a cannon-ball, are retained in their vast orbits by the same power which causes a stone to fall to the ground ; that this power, with their various motions, moulds those bodies into the forms they have assumed ; that their motions and the arrangement of their paths cause their mutual action to operate in such a manner, as to make their course constantly vary, but also to prevent them from ever deviating beyond a certain point, and that the deviation being governed by fixed rules, never can exceed in any direction a certain amount, so as to preserve the perpetual duration of the system ;—such truths as these transport the mind with amazement, and fill it with a pure and unwearying delight. This is the first and most legitimate pleasure of philosophy. As much and the like pleasure is afforded by contemplating the truths of Moral Science. To trace the connection of the mental faculties with each other ; to mark how they are strengthened or enfeebled ; to observe their variety or resemblance in different individuals ; to ascertain their influence on the bodily functions, and the influence of the body upon them ; to compare the human with the

brute mind ; to pursue the various forms of animal  
 instinct ; to examine the limits of instinct and  
 reason in all tribes ;—these are the sources of as  
 pleasing contemplation as any which the truths of  
 abstract or of physical science can bestow ; from  
 these contemplations we reap a gratification un-  
 alloyed with any pain, and removed far above all  
 risk of the satiety and disgust to which the grosser  
 indulgences of sense are subject. But the study of  
 Political Science is equally fertile in the materials  
 of pleasing contemplation. The examination of  
 those principles which bind men together in com-  
 munities, and enable them to exercise their whole  
 mental powers in the most effectual and worthy  
 manner ; the knowledge of the means by which  
 their happiness can be best secured and their virtues  
 most promoted ; the examination of the various  
 forms in which the social system is found to exist ;  
 the tracing all the modifications which the general  
 principles of ethics and of polity undergo in every  
 variety of circumstances, both physical and moral ;  
 the discovery of resemblances in cases where  
 nothing but contrasts might be expected ; the  
 observation of the effects produced by the diver-  
 sities of political systems ; the following of schemes  
 of polity from their most rude beginnings to their  
 greatest perfection, and pursuing the gradual  
 development of some master-principle through all  
 the stages of its progress—these are studies which

would interest a rational being, even if he could never draw from them any practical inference for the government of his own conduct, or the improvement of the society he belonged to—nay, even if he belonged to another species and was merely surveying the history and the state of human society as a curious observer, in like manner as we study the works of the bee, the beaver, and the ant. How prodigiously does the interest of such contemplations rise when it is the political habits of our own species that we are examining, and when, besides the sympathy naturally felt in the fortunes of our fellow-creatures of other countries, at every step of our inquiry we enjoy the satisfaction of comparing their institutions with our own, of marking how far they depart from the same model, and of tracing the consequences of the variety upon the happiness of millions of beings like ourselves ! How analogous is this gratification to the kindred pleasure derived from Comparative Anatomy, which enables us to mark the resemblances and the differences in structure and in functions between the frame of other animals and our own !

From the contemplation of political truth our minds rise naturally, and by a process also of legitimate reasoning like that which discovers those truths, towards the great Creator of the universe—the Source of all that we have been surveying by the light of science—the Almighty Being who



made the heavens and the earth, and sustains the frame of the world by the word of His power. But He also created the mind of man, bestowed upon him a thinking, a reasoning, and a feeling nature, placed him in a universe of wonders, endowed him with faculties to comprehend them, and to rise by his meditation to a knowledge of their Great First Cause. The Moral world, then, affords additional evidence of the creating and preserving power, and its contemplations also raise the mind to a communion with its Maker. Shall any doubt be entertained that the like pleasing and useful consequences result from a study of Man in his political capacity, and a contemplation of the structure and functions of the Political world? The nice adaptation of our species for the social state; the increase of our powers, as well as the multiplication of our comforts and our enjoyments, by union of purpose and action; the subserviency of the laws governing the nature and motions of the material world to the uses of man in his social state; the tendency of his mental faculties and moral feelings to further the progress of social improvement; the predisposition of political combinations, even in unfavourable circumstances, to produce good, and the inherent powers by which evil is avoided, compensated, or repaired; the singular laws, partly physical and partly moral, by which the numbers of mankind are maintained, and

the balance of the sexes preserved with unerring certainty ;—these form only a portion of the marvels to which the eyes of the political observer are pointed, and by which his attention is arrested ; for there is hardly any one political arrangement which by its structure and functions does not shed a light on the capacities of human nature, and illustrate the power and the wonders of the Providence to which man looks as his Maker and Preserver. Such contemplations connected with all the branches of science, and only neglected by the superficial or the perverted, are at once the reward of philosophic labour, the source of true devotion, the guide of wise and virtuous conduct : they are the true end of all our knowledge, and they give to each portion of it a double value and a higher relish.

The last—but in the view of many, probably most men, the most important—advantage derived from the sciences is their practical adaptation to the uses of life. It is not correct—it is the very reverse of the truth—to represent this as the only real, and, as it were, tangible profit derived from scientific discoveries or philosophical pursuits in general. There cannot be a greater oversight or greater confusion of ideas than that in which such a notion has its origin. It is nearly akin to the fallacy which represents profitable or productive labour as only that kind of labour by which some

substantial or material thing is produced or fashioned. The labour which of all others most benefits a community, the superior order of labour which governs, defends, and improves a state, is by this fallacy excluded from the title of productive, merely because, instead of bestowing additional value on one mass or parcel of a nation's capital, it gives additional value to the whole of its property, and gives it that quality of security without which all other value would be worthless. So they who deny the importance of mere scientific contemplation, and exclude from the uses of science the pure and real pleasure of discovering, and of learning, and of surveying its truths, forget how many of the enjoyments derived from what are called the practical applications of the sciences, resolve themselves into gratifications of a merely contemplative kind. Thus, the steam-engine is confessed to be the most useful application of machinery and of chemistry to the arts. Would it not be so if steam-navigation were its only result, and if no one used a steam-boat but for excursions of curiosity or of amusement? Would it not be so if steam-engines had never been used but in the fine arts? So a microscope is a useful practical application of optical science as well as a telescope—and a telescope would be so, although it were only used in examining distant views for our amusement, or in showing us the real figures of the planets, and were

of no use in navigation or in war. The mere pleasure, then, of tracing relations, and of contemplating general laws in the material, the moral, and the political world, is the direct and legitimate value of science; and all scientific truths are important for this reason, whether they ever lend any aid to the common arts of life or no. In like manner the mental gratification afforded by the scientific contemplations of Natural Religion are of great value, independent of their much higher virtue in mending the heart and improving the life,—towards which important object, indeed, as the contemplations of science more or less directly tend,—and in this higher sense all the pleasures of science are justly considered as Practical Uses.

But the applications to the common affairs of life, which generally go by that name, are also of great value. The Physical Sciences are profusely rich in these. The speculations of the moralists are also of great value in teaching us the discipline of the understanding, in improving the feelings, and in cultivating virtuous sentiments; they are of still greater service in helping those concerned about the government of men. But the study of Political Philosophy is certainly, of all others, the most fruitful in beneficial results of what is usually called a practical kind. If almost proverbially “the proper study of mankind is man,” the most important application of the doctrine



which moral science teaches respecting his nature is unquestionably that whereby we learn his position, habits, interests, rights, and duties as the member of a civil community. The science which treats of the structure of government, which makes the experience of one age or nation benefit another, and save it the price, and inconvenience, and delay of failure, pointing out the errors committed in various systems of civil or commercial polity, showing how these are to be corrected or shunned, and showing how such systems may most effectually and most safely be improved so as to secure the happiness of the people—the science which expounds the best modes of legislation, the true principles of jurisprudence, the more efficacious manner of executing, as well as of making laws—which defines the rights of the people and their duties, as well as those of their rulers, explains the rights of one nation with respect to another, and shows both the duty and the wisdom of combining order with freedom at home, and independence with peace abroad:—surely this science, if it be not, of all others, the most useful to every state, nay to every individual citizen at every period, at least yields to none in real practical importance. The benefits which it helps us to obtain, the errors which it leads us to correct, the dangers which it enables us to avoid, are the most important, because those benefits, and errors, and

dangers affect the whole affairs of nations, and nearly concern every individual member of the community directly or indirectly. Nothing can be more plain than this proposition; but incidentally it will derive additional illustration when we now proceed to consider the objections which have been sometimes raised against teaching it. To take only one illustration at present—how nearly does the advantage resulting from the examination of foreign constitutions resemble the benefits derived to human Physiology from studying the anatomy of the lower animals! This branch of Political Science may be justly termed the Comparative Anatomy of Government; and if studied with a constant regard to general principles of policy, their illustration from the structure and functions of various systems of polity, and the modification they undergo by the diversities of each, this science is calculated to throw useful light on the general subject of Political Philosophy, and lend us valuable improvement to the knowledge of our own system, exactly as the Comparative Anatomy of the body extends our knowledge of Physiology, and improves our acquaintance with the human frame.

No one has ever, in any free state, hardly in any civilized country, denied the advantages of Political Science, or objected to its being learnt by certain classes; nothing so absurd was ever yet attempted.

But an opinion at one time prevailed, and it still has some adherents, that political subjects are not fit for discussion among the great body of the people, and that, therefore, many who do not deny the propriety of instructing them in other branches of knowledge, have objected to their being taught the doctrines of Political Philosophy. The rich and the powerful might study such matters; the rulers and the lawgivers of the country, or the upper classes of the community, might learn them, and treatises might be written for, or lectures delivered to, them and their children, or addressed to other select circles, upon the great subjects of National Polity: but the people were to care for none of these things,—they might read a newspaper or attend an election meeting; but political knowledge was a thing above their reach and out of their line,—a thing for their betters, and with which it was both useless and perilous for the working classes to meddle. The time is certainly past and gone, never to return, when such preposterous doctrines could find any general acceptance in this country or in France; though in other parts of Europe they still are found to pass current. Yet even in France, Germany, and England herself, a modification of the same fallacy is to be traced as influencing the judgments of many respectable men, even of some whose general opinions are not bigoted or illiberal: it leads to the enter-

taining a strong prejudice against the diffusion of political knowledge, to a wish that the people at large could be cured of their taste for it, and to an alarm at the dangers likely to result from it to the peace and good order of society. It becomes a duty, therefore, to examine a little more closely this objection, and see whether it really has any force. Let us begin by stating the argument used by the objectors; but, first of all, let us observe that the main objection is to Politics, as contradistinguished from Political Economy; that is, to the first subdivision of the great branch of Domestic Policy. Of its other subdivisions, Economic Science, and of the second branch, International Policy, the objectors are more careless, and some would rather have the former of these—Political Economy—taught, provided Politics, commonly so called,—that is, the principles, and structure, and functions of government, were exempt from the public scrutiny, and withdrawn from the province of the popular teacher.

The argument of the objectors is this,—No human institution is or can be perfect: and the governments established in all the countries of Europe having their origin in early and unenlightened times, necessarily partake more or less largely of the imperfection incident to the works of man. They present, therefore, many points of objection to those who live in a more refined period



of society ; nor is it possible to deny that many things would be avoided as absurd or pernicious in the present times, if we had now to frame, for the first time, our political institutions. It thus becomes impossible to examine either our own or other systems of government without pointing out many faults in them ; nor can the sound principles of civil polity be unfolded without leading to inferences disparaging to the system we live under. Nay, it would be impossible, and, if it were possible, it would be dishonest to shun the reference to existing circumstances and the established order of things in explaining the fundamental principles of sound policy, against which the institutions of the state are found clearly to sin. Hence it is argued, that the people, being thus taught, are rendered discontented with their government, and excited to a desire of change.

1. We may begin by observing that much of the real force of this objection is presented against a factious, unfair, exaggerated discussion of political subjects, undertaken in the disguise of a fair and honest course of instruction. That treatises, and still more, lectures to the people, may have a pernicious effect if the teacher abuses his office, and makes himself a partisan or a demagogue, is not denied. But it by no means follows that the science of government may not safely be taught. For, after all, it is a practical, an experimental

science. If there be no real mischiefs occasioned by any alleged defects in any given system of polity,—if the evils charged upon it are merely speculative and almost nominal,—if the people do not feel any inconvenience from them,—if they produce no consequences which are generally seen, and by all who observe them freely admitted,—nay, if the evils be not actually felt as well as remarked and confessed,—we may be well assured that the allegation of the defects existing will be received as groundless, because, practically speaking, the arrangement called in question is not defective. No argument in a speech, no exhortation in a treatise or a lecture, can make men think they are oppressed, or ill governed, or suffering in any way, when they are in reality free and happy; or can succeed to a considerable extent in persuading the audience or the disciples that they are uncomfortably circumstanced, and ought to be discontented, when they know and feel that they are living at their ease and ought to be satisfied.

2. But suppose the defects do exist, and that the people suffer under them, it is fit and proper that the causes of the evil should be probed, and should be pointed out without any reserve. It is certain that the not doing so will never prevent the people from feeling discontented; on the contrary, if they are left to feel the pressure, and do not know distinctly from whence it proceeds, both their discon-

tent is likely to be increased beyond its just amount, and it is likely to take a wrong direction. The lessons taught by honest and skilful instructors will both reduce the complaint within the bounds of moderation, and prevent blame from being imputed to harmless measures, inoffending men, and unexceptionable institutions. If any illustration were wanting of the dangers to which the peace as well as the general prosperity of a country may be exposed from popular ignorance, we might instance the disturbances so often arising in all parts of the world from the popular indignation against the exporters of corn during a scarcity, or the use of machinery in times of manufacturing distress. But ignorance of the nature of government may produce the like mischiefs.

The necessity of some considerable degree of restraint to the well-being of society—the impossibility of the supreme power being left in the hands of the whole people—the fatal effects of disregarding the right of property, the great corner-stone of all civil society—the interest which all classes down to the humblest have in the protection afforded by law to the accumulation of capital—the evils of resistance to established government unless in extreme and therefore very rare cases—the particular interest which the whole people, low as well as high, must ever have in general obedience to the supreme power in the state—the almost uniform

necessity of making all changes, even the most salutary, in any established institution, gradually and temperately—all these are the very first lessons which every political teacher must inculcate if he be fit for his office, and commonly honest, and he cannot move many steps in any direction through his subject, without finding occasion to illustrate and to enforce these fundamental lessons by the constant experience of mankind. But what are these lessons? They are the very doctrines of good order and of peaceful conduct; they are the most powerful incentives to submission—a submission the more to be relied on, because it is rational, and results from an appeal to men's reason, not from an overruling force—the well considered submission of well-informed and therefore well-disposed men, not the blind obedience of ignorant slaves. Let the body of the people be kept ever so much in the dark upon the nature of government and the state of their own concerns, the existence of evils being admitted, the smarting under them will come without any teaching; but the more they learn the better they will be able quietly to bear them. Let the people be ever so ignorant, the sense of their own exclusion from a power which they see their superiors exercise, one of the hardest things to bear—the comparison of the poor man's lot with that of his wealthy neighbour, the very hardest portion of their lot, and that which must



ever expose society to its greatest perils—will be always sure to strike their minds ; and unless they are curbed by an overwhelming force, can never operate without the most mischievous tendency to the peace of society, until the foundations of government and the nature of the social compact, as well as the principles of Economical Science, are fully learnt by the mass of the people. There wants no teacher to make a poor man begrudge his powerful and wealthy neighbour both his actual share in the government and his disproportionate share in the good things of this life : but the teacher must have ill performed his task if he has left any doubt in the mind of the poorest man who hears or who reads him, that the misery of all classes must follow from insurrection and anarchy ; that unequal distribution of power is necessary for all government, and unequal distribution of property essential to its very existence, the idea of too much and too little being utterly inconsistent with its very nature ; that upon its existence depends the whole fabric of society ; and that a general division of possessions would make the country a scene of profligate extravagance for one year, and of universal desolation the next—a bedlam for one short season, and a charnel-house ever after.

3. The contemplation of the structure of other governments as well as of that under which we live, and the comparison of the defects and advantages of

our own with those of other systems, can hardly fail to produce a happy effect upon the dispositions of any people in tolerably happy circumstances. Our countrymen, for example, when they perceive the immeasurable superiority of the British over so many other forms of government, cannot avoid drawing from the comparison powerful motives for contentment, and strong reasons why they should bear with subordinate evils rather than run the risk of losing a great good. All foreign experience, too, and all past history, inculcates the necessity of sober and cautious proceeding, where admitted evils are to be removed, or valuable improvements to be introduced. Nor can it escape observation, that many of those things which the superficial and ignorant are prone to regard as improvements, are easily shown, by a deeper examination of the subject, to be either useless or hurtful. Hence untaught men often long after some foreign institution about which they know little; whereas a full and systematic acquaintance with the subject would show them that the different habits and various circumstances of the foreign nation, in other particulars, render the thing in question beneficial there, which here would be noxious.

4. It would be endless to show in how many particulars a people would be more easily and safely governed, if political knowledge were fully and widely diffused among them. The first instances

that occur are drawn from the evil influence of ignorance and prevailing errors upon subjects of Economical Science. The great mischief arising from the labouring part of the community being unacquainted with the nature of *wages*, and the principles on which their rate depends, are well known. The unlimited supply of labour which their imprudent marriages, and repugnance to change their residence or their occupation, are constantly bringing into the market, really is the main cause of the depression of the working classes ; for it keeps down their earnings to the very lowest amount of subsistence on which human life can be maintained. Could anything be more happy, both for themselves and for the peace of society, than such a thorough knowledge of this subject as would check the master evil which now pervades all the lower ranks of society ?—In like manner, the outcry raised in favour of unlimited provision for the poor, and against the reasonable, indeed the necessary rule which would confine each man to living upon the produce of his own industry, or the income of his own property, never could arise, at least never could have any success, but among the the most ignorant of mankind.—So, the strange delusions propagated by some wild visionaries, and by some ill-disposed men, that labour alone gives a right to enjoyment, and that the existence of accumulated capital is a grievance and an abuse, could

not have the least success with men who had been taught to reflect that the accumulation of capital is the necessary consequence of the existence of property and its secure possession, and that no classes have a stronger interest in the protection of capital than the labourers whom it must necessarily always be employed in supporting.—The rage against machinery ; the objections to a free export of grain ; nay, the exaggerated views of even just and true doctrines, as that which condemns the corn laws ; afford additional illustrations of the mischiefs which ignorance of economical science is calculated to produce.—To take one more example, but a very striking one, —the popular prejudice against usury, and the notion that limiting the rate of interest protects distressed borrowers, prevented any attempt to amend the law in that important particular for many years after Mr. Bentham had demonstrated that the distressed borrower suffers far more under this pressure than the wealthy lender, and after the first mercantile authority in the world\* had pronounced Mr. Bentham's 'Defence of Usury' unanswered, because unanswerable. Nor have the higher classes yet thrown off these prejudices so far as to remove altogether one of the greatest practical defects in our commercial jurisprudence.

\* The late Sir Francis Baring.



But the teaching of other branches of Political Science is equally beneficial to the cause of good government. It may safely be affirmed that no outcry against any impost required for the public service ever could be raised among a people well informed on the necessity of maintaining the establishments required for the public service; and that such schemes as the Excise never could for years have been defeated, and afterwards made for half a century the object of popular hatred, sometimes the ground of insurrection, in a well-informed community. So the vulgar prepossession in favour of law-taxes, as tending to check litigiousness, could only among a very ill-informed people have supported, till a late period, an impost notoriously the very worst that ever was invented, and the direct tendency of which is to prevent justice from being obtained by the poor man.—The cry of sacred chartered rights being violated by a reform in a monopolizing Company's administration of India, drove a ministry from power three score years ago; and assuredly it could never have seduced any but a very ignorant people. Accordingly, there was just as much violence done to the Company's charter, the year after, by the successors of that ministry, without any kind of umbrage being given to the most sensitive persons in the country.—The classes of society were among the most ignorant of mankind, which about the same time were seized

with such an alarm lest Popery should be made, by main force, the religion of the people, that they attempted to fire London, did burn the Catholic chapels in Edinburgh, and drove into retirement the most accomplished member of the Scottish Church,—the illustrious historian whose works shed a lustre on the name of his country.\* Nor were those better informed who, thirty years later, helped a party in the state to remove their adversaries from the government, and seize upon their places, upon the outcry of a like danger threatening the religion of the country in consequence of a very insignificant bill, which its adversaries passed into a law a few years afterwards without one word being ever whispered against it.—But let us consider only how many measures every government is compelled to postpone, contrary to its fixed and clear opinions, merely because the public mind will not bear them in its present state of information. Men may differ, for example, as to the propriety of retaining certain colonial possessions at a vast expense, with great loss to our trade, and with considerable risk of hostile operations becoming necessary. But even if all statesmen of any note were agreed that those distant possessions should be abandoned, what minister would venture to give up the country where Wolfe gained his victory and met his end,—an

\* Robertson.

event that has consecrated the spot in the affections of the people, and makes them blind to all consequences and deaf to all reason?—So it might be of great benefit to give up Gibraltar; but the people must have learnt many a lesson of political wisdom before it would be safe for any administration to propose its cession, how ample soever might be the benefits of the measure. Lord Chatham was as bold a minister, and one as regardless of consequences when he saw his course clear before him, as ever presided over the affairs of this country;—yet, when, in order to gain the invaluable co-operation of the Spanish branch of the Bourbons, and rescue Europe from the depression consequent upon its disjointed state, he perceived the expediency of offering up Gibraltar for Minorca, a letter from him to our ambassador at Madrid remains, in which he broaches the subject with a degree of fear and trembling that indicates how frightful he deemed the risk he ran of exciting the national feelings of England against him to overwhelm his government. Such alarms could have no place among a people, the bulk of whom, well informed upon political subjects, were accustomed to consult the real interests of the country, and incapable of being led astray either by vague apprehensions, or the clamours which designing knaves might raise to delude them.—But of the many evils which popular ig-

norance creates in human society, there is none so pernicious as its influence upon those national feelings in which commercial restraints, and, above all, wars, have their origin. The fear of benefiting other nations, and aiding our competitors by our trade, is at the bottom of the former ; the latter are too frequently occasioned by national animosities, by hatred of our neighbours merely because they are our neighbours ; and it may be remarked that both commercial and political jealousies chiefly operate against those who, for the very reason that they are our near neighbours, are our best customers, and should, for the benefit of both parties, be our firmest friends. The history of our species is a history of the evils that have flowed from a source as tainted as it is abundant. To go no further back than a century ago,—Walpole was first hurried into a war which its chief supporters afterwards admitted\* to have been as groundless as it was impolitic, by a senseless cry against the Spaniards, raised by a few smugglers, who took advantage of our people's ignorance to excite their feelings of honour and revenge, and profligately encouraged

\* Mr. Burke relates this striking instance of the crimes of party : to turn out Walpole, his adversaries raised the war-whoop ; they broke the peace of twenty years to obtain power. This those party-leaders admitted to him in discussing this disgraceful passage of party history.



by a political party who turned to their own personal advantage the greatest injury they could inflict upon their country.—The most unfortunate and impolitic war ever waged by this country was popular in the extreme at first; and no minister could have stood up against the supremacy of the mother-country over thirteen colonies, while all the ignorant members of the community believed that they had an interest in levying taxes by force from the American colonies in aid of the mother-country.—Nor is it any diminution of the evils which are produced by want of political knowledge, that wars, in themselves just and necessary, may at first be favoured by the people, and then abandoned at a time when the best interests of the state require them to be persevered in. An unreflecting, because an uninformed, nation is at all times liable to commit this error, than which none can be greater excepting that most grievous of all faults, the rushing into a contest without cause.

5. It may be said that there is this peculiar to a course of political instruction, that many of the principles explained in it are those which the existing parties in the state are at the time appealing to, and disputing about,—many of the illustrations used in expounding those principles are the very topics of most vehement discussion among the practical statesmen and factions of the day. The whole subject, it may be argued, is more or less contro-

versial, and the controversy is one in which, as it involves men's real or supposed interests, and consequently engages their passions deeply, no instructor can easily avoid taking a side, and no audience can help being swayed by the prevailing sentiments of the times ; so that instruction becomes difficult, from the interference of party prejudice in both the teacher and the pupil, while a factious spirit is sure to be fostered, and unkindly feelings to be exacerbated, if not engendered. In this remark there is, unquestionably, much truth ; it refers to the principal difficulty that attends political instruction. But it can never be allowed to prove that no such instruction should be conveyed ; it only warns us to guard as much as possible against falling into the error which it points out. If it were suffered to operate as a conclusive reason against teaching politics, this would follow—that upon the things most necessary to be known ignorance is better than knowledge,—that in proportion as the subject is more interesting to men, they should take the less pains to understand it. But that is not all : it would also follow that, upon topics calculated to excite strong feelings, it is better and safer for the people to be kept in the dark. For by the supposition which forms the ground of the whole objection, you cannot keep the people from taking an interest in these subjects ; you cannot help their being excited and split into

parties; their being so is the very origin of the remark with which we are dealing. Then, because such excitement and such party differences prevail, is there any common sense in prescribing an entire ignorance of the questions those dissensions relate to, as a likely means of allaying them? Are political differences the more sure to be reconciled by keeping those who are split by them in ignorance of the subjects under dispute? Are men more likely to agree upon any matter the less they know about it? The people, it seems, feel strongly upon certain subjects, and are much divided in opinion, many being for a certain course of policy, many against it. The argument is, that for the purpose of bringing about an understanding, and making all in its favour, or all join in rejecting it, or all unite in preferring some middle course safely placed at a distance from either extreme, the parties should be prevented from comprehending the nature of the measure in question, and kept in ignorance of all the arguments for it, all the arguments against it, and all the arguments for a middle course. Once upon a time, says the old fable, two gallant knights met upon a plain where a shield stood upright; and one of them having called it a white shield, the other asserted it to be black, whereupon they prepared to fight after the manner of that age, still somewhat in vogue at the present day. But a dervise or priest came up, and, having learnt the

cause of their quarrel, suggested that each had better look at both sides of the buckler—when they found that each knight was right—the one side being pure white, the other jet black. The minister of peace performed his duty wisely ; but our objectors, and some of them nominally of the same vocation with the dervise, have no better expedient to propose than that the shield should be covered up from both combatants, and the fight go on.

It must on all hands be admitted that there is no greater evil in any country than party violence—the abuse of that which, if kept within due bounds, is an advantage, and may be the means of preserving public liberty and promoting general improvement, namely, the honest combination of statesmen for patriotic purposes. This becomes an intolerable evil when it is made the mere engine of selfish men for giving power and profit to themselves at the expense of the public good, and by the subservient agency of the people whose interests are sacrificed to the views of their leaders. Opinions are then assumed, in order to marshal politicians in bands and separate them from others. Place is the real object ; principle the assumed pretext. The people, instead of thinking for themselves, are made the dupes and the tools of others,—hurried into all the follies of which thoughtless men are capable, and into as many excesses as their designing leaders dare let them commit consistently with their own



safety, and without the least regard for that of their followers. Now, nearly the whole influence of such party chiefs is grounded upon the political ignorance of the people at large ; and the permission thus assumed to make and dictate their opinions. In such a state of things Dean Swift's saying is correct, that " Party is the madness of many for the gain of a few ;" and such a state of things could not exist among a people politically educated. As the navigators who first visited the South Sea Islands could purchase the lands, goods, and chattels of the natives for a red feather, our ancestors four centuries ago could butcher one another by thousands, and extirpate nine-tenths of the nobility of the country in a few years for a red or a white rose ; but the wars of Lancaster and of York could no more be waged in our time, than the South Sea islanders, after being civilized, can be induced to barter their property for nothing ; and the day will come when other party differences will be regarded with the same contempt with which we now regard the factions of the Henrys and the Edwards.

6. This leads to the important remark, that the question is no longer left open to us whether the people shall be taught politics or not. Taught they must be ; and the only question is, whether they shall be well taught, or ill instructed and misinformed. Do what you will, somebody will take the part of public instructor. It is an office

that any man in a free country may assume, and it is one which almost every one thinks himself qualified to fill. If the people are not taught sound doctrine upon the subject, by calm and tolerably impartial men, they will inevitably listen to guides of a far different description, and will fall a prey to the more violent and the more interested class of politicians, to the incentives of agitators, the arts of impostors, and the nostrums of quacks. If, indeed, a teacher so far violates his duty, as to give partial, inflamed, untrue accounts of the subject he handles—if he keeps out of view the facts which history has stored up in illustration of the tendency of particular systems—if he inflames the passions of an unthinking multitude, and converts a course of instruction into an engine of faction,—then he may do mischief, as all men may who are guilty of fraudulent and mischievous actions upon false pretences. But this possibility only furnishes a reason against misinstructing the people, not against teaching them; it warns us to avoid impostors, not instructors; it shows that politics may be ill and dishonestly taught, as religion, or even morality itself may be; not that politics should be left untaught any more than morals and religion. And assuredly we may rest satisfied of one thing; the difficulty is far greater, of making a course of lectures the means of propagating, by foul means, any system of opinions, than the difficulty of de-

ceiving the people in any other way. The shame, upon the detection of such a design, is far greater, and the chances of its being detected are more numerous. The good dervise, of whom the legend speaks, took the honest and the rational course ; he was as fair as well as a wise teacher. Had he, like the Levite in the parable, kept aloof and passed on the other side, while the work of death was going on, he would have been a weak, and a timid, and a selfish man. But had he interfered to prevent the combatants looking on both sides—had he, who saw the shield in either direction, persuaded each knight that he was in the right, and that the other was in the wrong, he would have been justly execrated as a dishonest guide—his treachery would have been speedily discovered—and both parties would have joined in scorning and in punishing him. Let it not, however, be supposed that any course of political lessons can be given with no leaning to one set of doctrines rather than another. Such a thing is hardly possible, consistently with honesty ; and, were it possible, it would not be at all desirable. On a subject like this every one who has well considered it must have formed his opinions ; and he must, therefore, conscientiously believe those opinions to be right—say, to be the only right and safe ones for the people to entertain. It is therefore his bounden duty to declare his sentiments ; and it is infinitely

more fair, more honest, and more useful, as well as safer, that he should declare them openly, distinctly, and manfully, after stating the whole case, and the reasons on both sides, than that he should give a partial view of the argument, and leave the audience to draw its own conclusions—that is, his own conclusions. He is a teacher, not a partisan; he is fairly to expound the views and the arguments of others with whom he differs; and he is to give his reasons for retaining his own sentiments. From so open and honest a course of proceeding no mischief whatever can be apprehended, and no other course can be called Instruction. Can any one doubt that it is best for the people and safest for the government that this course should be pursued upon all political subjects, and most of all upon those subjects which are the most calculated to excite deep interest and rouse strong feelings? What better means can be devised of showing the public how much it is their interest to inquire and judge for themselves? What better security can be devised against the efforts of violent and intriguing men? What more sure remedy against the arts of political-empirics, whose natural prey is, and ever will be, the ignorant vulgar—but who in vain display their wares before well-informed and reasoning men?

These considerations may serve to show, not merely that the Political Education of the people



is attended with none of the danger to the peace of society which the objectors apprehend, but that a positive security is afforded by it against the very worst dangers to which the cause of good order in any community can be exposed. But we must go yet a step further, and observe that the right of the people to be instructed as to the public interests, and the duty of their superiors to educate them in Political Science, rests upon higher ground than has yet been taken.

The force of public opinion must be acknowledged in every government, save only that of the most purely despotic form. It has more or less a direct influence, according to the nature of the constitution under which the people live; and the momentum with which it acts varies, under the same kind of constitution, according to the degree in which the people are educated. But even in countries that enjoy little constitutional freedom, the public voice, when raised, is effectual; and even the most ignorant nation has a will which its rulers must not venture entirely to disobey: nay, in absolute monarchies, where public opinion forms the only check on misgovernment, and the people seldom exert any influence, yet, when they do interfere, it is oftentimes with terrible effect. Nor is any interposition likely to be withheld merely because, from the popular ignorance, it happens to be uncalled for or exerted in a wrong direction. How

important, therefore, is it, with a view to the people's only safeguard, and the ruler's only curb, that they should be well-informed upon their political interests! But how immeasurably more important is it in countries living under a free government, that those whom the constitution recognises as sharers, more or less directly, in the supreme power, should have a correct knowledge of the state of their own affairs, and the principles upon which their rights and their interests depend! It must be observed that no government, even the freest, can be in the hands of the people at large; and that grand improvement of modern times, the representative system, by which extent of territory can be safely combined with a popular constitution, still leaves the exercise of supreme power in the hands of persons delegated to govern—even where there are none but elective magistrates, that is, even in republican constitutions. Those delegates, then, be they executive, or judicial, or legislative, require the vigilant superintendence of the community, in order to prevent errors or abuses, to quicken their diligence or to control their faults, during the term of their office. This superintendence is most wholesome if exercised by an enlightened people, and affords the only effectual security for constant good government—the only real safeguard for popular rights. How many fatal errors would rulers of all kinds, and in all ages—whether

Consuls and Senates, or Archons and Assemblies of the people, or Monarchs and their Councils, or Kings and their Parliaments, or Presidents and Chambers, have been prevented from falling into; and how many foul crimes, both against the interests of their subjects, and against the peace and happiness of the world, would they have been deterred from committing had the nations submitted to their care been well instructed in the science of public policy, acquainted with their true interests, aware of the things most dangerous to their liberties, and impressed with that sense of duty to their species which an enlarged knowledge of Political Philosophy can alone bestow! Take, again, the instance of war—that game, as has been well said, at which kings could never play were their subjects wise—how melancholy is it to reflect that nearly all the devastation which it has spread over the earth would have been spared, with the countless mischiefs following in its train, had only the same enlightened views prevailed which have already resulted partly from sad experience, partly from diffused information, and which seem, at the present day, to have, at least for a while, taught men the guilt as well as the folly of war! But experience is a costly as well as an effectual teacher; and the same lesson might have been wholly learnt without the heavy price that has been paid for it. Experience, too, is a teacher whose lessons are forgotten

in the course of a little time ; as the memory of wounds and the fear of fighting wear out with the pain they occasion. Nothing, then, can effectually and permanently instil the sound doctrines of peace and of justice into any people but an extensive Political Education, to instruct them in their interests and their duties. It is the same with the frauds as with the oppressions of statesmen. The sacrifice of the many to the few would be impossible in a well-informed country. That game of party, in which the interests of the people are the counters, and the power and pelf of the gamesters themselves the only thing they play for, though not the only stake they risk, never could be played to the destruction of public virtue and the daily peril of the general good, were the people well acquainted with the principles which should govern the administration of their concerns ; and possibly it is an instinctive apprehension of this truth that has made all parties so averse to the general diffusion of political knowledge.

But it is not merely as a control on the mismanagement of their affairs, and a check to encroachments on their rights, that the interposition of the people is required in every country, and is the very life and soul of each constitutional system ; they ought to promote the progress of improvement, by urging their rulers to better by all means the condition of those under their care, and, above every-



thing, to amend the errors of their political system. As all government is made for the benefit of the community, the people have a right, not only to be governed, but to be well governed ; and not only to be well governed, but to be governed as well as possible ; that is, with as little expense to their natural freedom and their resources as is consistent with the nature of human affairs. Towards this point of perfection all nations ought constantly to be directing their course. But the rulers having no interest of the kind—nay, rather an interest in keeping things as they are, if not making them go backwards—unless the people interfere, little progress will be made in that direction, and some risk always incurred of losing the ground already gained. Surely, then, nothing can be more manifest than that full and sound political information is necessary for those whose strongly pronounced desire of improvement is the best security for the progress of all national reform. The diffused knowledge of the general principles of policy, and an intimate acquaintance with what has been done in other countries, and with the results produced, becomes as sure a source of political improvement as the diffused knowledge of mechanical science, and an acquaintance with the inventions of foreigners, is the source of almost all improvement in the arts. The education of particular classes alone may, no doubt, be better than the general prevalence of

political ignorance ; but as those classes for the most part have particular interests, and each has its own purposes to serve, the only security for improvements which may benefit the whole body of the people, is for the whole body of the people to understand in what their true interests consist.

In truth a greater absurdity cannot well be imagined, than attempting to keep the bulk of mankind in ignorance of all that appertains to State Affairs. State affairs are their own affairs. An absolute Prince\* once exclaimed, “ The State ! I am the State ! ” But the people may most justly exclaim, “ We are the State. ” For them laws are made ; for them governments are constituted. To secure their peace, and protect them from injury without and within the realm, rules are appointed, revenues raised, police established, armies levied. To exclude them from the superintendence of their own affairs is as if the owner of an estate were refused the inspection of his accounts by his steward. To prevent them from understanding the principles on which their affairs are administered, is as if the owner of an estate were suffered to know what his steward was doing, but debarred from all understanding of what he ought to do. To prevent them from knowing what are the institutions and the condition of

\* Louis XIV.

foreign nations, is as if the owner of an estate were precluded from knowing how his neighbour's property was managed, what rent he got for his land, what salaries he paid his agents. In every country, whatever be the form of its government, and however little of a popular cast, this is the amount, and this is the aspect of the absurdity propounded by those who would prohibit the Political Education of the People. But incomparably grosser is the absurdity of keeping the people in ignorance where the constitution of the government is of a popular kind. There, the people are called upon to bear a share in the management of their own affairs, to attend public meetings, to serve in offices, to vote in the choice of lawgivers. There may be some consistency in excluding them from all the knowledge that would fit them for performing those high political functions, while you also exclude them from all exercise of the functions themselves. But to make them political functionaries, and to leave them in ignorance of political subjects, is little less absurd than it would be to keep the owner of an estate ignorant of farming, and expect him to superintend the management of his farms. But if it be said that there is no occasion for all the community learning Political Philosophy any more than there is for all a land-owner's family inspecting his accounts and understanding agriculture; the answer is obvious, that

all the community, and not particular classes, are the parties interested in State affairs ; and that if any family can be found in which all the members, servants included, have their several shares in the property of the estate, then, beyond all question, each member, down to the humblest menial, however inconsiderable his share of the property, would be entitled to inspect the accounts—would be directly interested in superintending the management—and would be unspeakably foolish to remain in ignorance of the principles on which farms should be managed, and the condition and management of the other estates in the neighbourhood.

Nor can any the least risk arise to the peace and good order of society from the humbler classes occupying themselves with such pursuits ; any, the least, risk of their grudging their superiors the benefits and the privileges of their station, or seeking to displace them, and shake the stability of the national system. Imperfect knowledge of Political Philosophy, a superficial acquaintance with what is passing in other countries, and what has, in past times, been the history of their own, may expose them to be misled by designing men, or to become the dupes of their own irregular desires and groundless fancies. Such errors are inseparable from all learning, because they are the consequences of the imperfect information with which learners must begin ; they overshadow the dawn of all intellec-



tual improvement ; they cloud the mind before the sun has yet arisen ; but they offer the same obstacles to knowledge in all its branches, and are as much objections to moral, and even to religious, instruction, as to the study of Political Science. The risk—the temporary and inconsiderable risk—is admitted ; the guarantee is certain, and it is easy. An imperfect light is dangerous. In the twilight men's steps falter ; and, as they dimly see, they doubtfully grope their way. Then let in more light ! That is the cure for the evil ; and that is the answer to the objection. But of one thing we may be well assured : be the dangers ever so great of instructing the people on that which it most concerns them to know—be the hazards arising from the circulation of free opinions and the diffusion of political knowledge among the people a thousand times more imminent than they have ever been painted by alarmed and short-sighted men ; we cannot prevent the evil, be it ever so appalling, and are left to apply the only remedy—“ Let there be light.” In vain you seek to put down such doctrines by force ; even to quell the uproar of admitted errors by force is of no avail in maintaining quiet. Rather say, force alone has the power greatly and widely to disseminate falsehood. Doctrines ever so fantastical, ever so wild—tenets as dull as they are groundless, as revolting as they are untrue—systems as rotten as

they are deformed—follies which, left to themselves, must quickly die a natural death—all are capable of being forced onward to success by injudicious attack. The rod of power, like the magician's wand, can change deformity into beauty, lend strength to the rottenness, give currency to the dulness, and life to the decay of errors, which nothing else could recommend, or circulate, or preserve. To oppose the progress of truth—to suppress the communication of opinions—to obstruct the diffusion of knowledge—is not so pernicious, but is quite as ineffectual an exercise of the persecuting power.

It remains to mark the most salutary effects of an extensive diffusion of Political Knowledge—the most salutary, because unalloyed by even any the least and most transient inconvenience. An enlarged view of their own best interests must give the people sound and enlightened feelings respecting the merits of human conduct, and form in them the habit of justly estimating the character and the conduct of the men who guide the affairs of nations. The mischiefs are incalculable which have resulted to our species, from the habitual false judgments formed on this important subject by the bulk of mankind; and it must in fairness be confessed that the great crimes which have been committed by statesmen in all ages, have been mainly caused by the encouragement which the people have given

to the criminals. Dazzled by success, subdued by the spectacle of triumphant force, stricken with wonder at the mere exercise of great faculties, and the sight of the events which they brought about, men have withdrawn their eyes from the means used to attain those ends, and lost their natural hatred of vice in their admiration of genius and their sense of power. No disgust at meanness, no scorn of treachery, no horror of cruelty, has hitherto availed against the false lustre shed over despicable and detestable deeds by brilliant capacity crowned with victory. But that is not all the folly committed by unreflecting men. The most absolute disregard to their own interests has been coupled with their misplaced admiration of successful guilt.

The crimes which dazzled them were perpetrated at their cost ; the price paid was their own long, and boundless, and bitter suffering. For all that was done amiss and for all themselves admired, they themselves paid. Their own best interests were sacrificed quite as much as principle and duty were violated. They have lavished upon tyrants, and conquerors, and intriguers, who were their worst enemies, their loudest applause ; for those pests of the world reserving the fame that should have been kept sacred to virtuous and beneficent deeds ; and confining the title of " Great "—the prize that all generous natures strive after—to those whose lives were spent in working their

misery and their ruin. This preposterous combination in which the people have so long been leagued to call things by their wrong names, to praise the wrong men, to suffer that the scourges of their kind, the enemies of peace and freedom and virtue, should not merely escape reprobation, but should monopolize all the places in the Temple of Fame, has been the fruitful source of human misery and national crimes, and it has been the result of nothing but the darkest ignorance. The knowledge of Political Science, which teaches the people their true interests, can alone rescue them from the error of ages—restore public virtue to the pedestal which successful vice has so long usurped—and secure on a lasting foundation the peace and the happiness of the world.

THE END.



## I N D E X

TO THE

TWO DISCOURSES OF THE OBJECTS, PLEASURES,  
AND ADVANTAGES OF SCIENCE, AND  
OF POLITICAL SCIENCE.

- 
- Absurdity of trying to keep the masses in political ignorance, 176; this absurdity grosser as the constitution is more popular, 177
- Accelerated motion, example of, in the falling stone, 33
- Advantages and pleasures of science, 95
- Air, the cause of vegetation, 108
- Algebra naturally springs from arithmetic, 13; notation of, and nature of its operations, 14; its superiority to arithmetic in solving problems, and as an instrument of discovery, illustrated, 15
- Anatomy, definition of, 37
- Animals, fitness of, to the circumstances in which they are found, 88
- Ants, labours and policy of, 83: their nests, *ib.*; keep slaves to prepare their food, 84; become torpid at the same degree of cold as their insect slaves, *ib.*; their gigantic size in tropical countries, 84; dimensions, siege, and bombardment of an ant-hill in South America, 85
- Apologue of the two knights and the shield, or look on both sides, 165
- Archimedes, boast of, 56

- Arithmetic, the nature and objects of, 12; how it differs from algebra, 13
- Arithmetical or numerical truths independent of the existence of matter or of space, 27, 28
- Arkwright; his practical knowledge of machinery, 101
- Astronomy, the objects of, 49; vast extent of the views afforded by, 52; ennobling nature of the study of, 114; quantity of matter in the sun, Jupiter, and Saturn, *ib.*; relative weights of the same substance on the earth and planets, *ib.*
- Attraction, law of, stated, 39, 41; influence and universality of, 42, 43, 110; the cause of tides, 48
- Axles of machinery; advantage of their being hollow, 7
- Balance of power, 137
- Beavers, habits of, 85; their skill in engineering and architecture, 86; their food, 87; division of labour, *ib.*; the overseers, 88
- Bee, construction of the cell of the, 73; the roof and floor, 74; evidence of design, *ib.*; angles of inclination of the planes of the roof, *ib.*; dimensions of the cell, *ib.*; method of gathering honey, &c., 76; mode of making a queen-bee, 82; grief for her loss, 83; opposition or obedience to a usurper a matter of time, *ib.*
- Bejuco plant, abundance of juice in the, 94
- Bentham's 'Defence of Usury,' allusion to, 158
- Birds, provided with an apparatus for flattening or rounding the eye, 68; the third eyelid, its use and motion, 70; their bones largest in proportion to their weight, advantage of this, 72; means by which they mount and descend with greater or less rapidity, *ib.*
- Bones of animals, why hollow, 72
- Botany, defined, 37; its connection with chemistry, 38
- Camel, appropriateness of the hoof and water-apparatus of the, 88; cushion of the foot of the, *ib.*

- Catenary, illustrations of the curve so called, 25
- Caution inculcated in introducing political reforms and improvements, 156
- Chatham, Lord, proposal of, to give up Gibraltar for Minorca, 161
- Chemistry, the objects of, 36; knowledge of, useful to bleachers, dyers, engineers, farmers, cooks, &c., 99; the wonderful discoveries of, 106, 107
- Circle, the, and its fundamental properties, 21; the angle in a semicircle, 21; illustration of the theorems that circles are to one another as the squares of their radii, 21; and that circumferences are as the radii, 22
- Comets move in very elongated ellipses, 43; in what they differ from the planets, *ib.*; their periodic times, 44; astounding velocity of their motion, *ib.*; subject to the universal law of attraction, 45; their amazing distance in aphelion, 51; and velocity in perihelion, *ib.*
- Common and statute law, distinguished, 135
- Comparative anatomy, defined, 37
- Cookery, the art of, improved by a knowledge of chemistry, 100
- Crimes of statesmen caused by the encouragement given by the people, 180; to their own cost, 181
- Cuckoo, nest chosen by the, to deposit her eggs, 91
- Curves, infinite variety of, 22; notice of those most commonly seen, 22-25
- Cycloid, mode of generating the, 25; remarkable property of the, *ib.*; the curve of equal times, 63; and of quickest descent, 64; eagle believed to move in this curve, *ib.*
- Delusions propagated by political quacks and incendiaries, 157
- Devastations of war, the consequence of want of enlightenment, 173
- Difference between the states of mind produced by novel-reading and scientific study, 112
- Difference between mathematical and physical truths, 25-36

- Diffusion of sound political knowledge the best security against designing demagogues, 170
- Discoveries and improvements seldom made except by persons of competent knowledge, 101
- Dogmatism, caution against, in metaphysical inquiries, 124
- Domestic policy of a state, defined, 131; sub-division of, 132
- Duck, peculiar formation of the bill of the, 91
- Duty of a government to give instruction in political science, 171
- Duty of providing subsistence for one's self and dependents, 97; habits of regular labour flowing from the exercise of this, 98
- Dynamics, definition of, 39; motion round a centre of attraction, *ib.*; law of attraction stated, *ib.*; a body acted on by this law will describe a circle, an ellipse, parabola, or hyperbola, according to the amount and direction of the original projective force, 40; elliptic orbit described, *ib.*; enunciation of the law expressing the relation between the squares of the periodic times and the cubes of the mean distances, *ib.*; law of gravity, 41; the moon subject to this law, 42; her orbit shown to be an ellipse, *ib.*; all the planetary orbits elliptic, *ib.*; influence and universality of attraction, *ib.* and 43
- Earth, the figure of, 48; diameter of, 50; distance from the sun, *ib.*; velocity of revolution, *ib.*; diurnal rotation, 51
- East India Company's charter, reform of, 159
- Electricity discovered by Dr. Franklin, 60; the same matter with lightning, 108
- Ellipse, or oval, mode of describing the, 23; fundamental property of the, *ib.*; generated from the section of a cone, 24
- Evil effects of a general division of property, 155
- Excise, popular hatred of the, 159



- Eye, structure of the, 67 ; its liquid magnifiers, 68 ; eyes of birds, 69
- Figures with which to fill a certain space without loss of room, 73
- Fishes, remarkable adaptation of the head to facilitate their motion, 64 ; use of air-bladder for rising and sinking, 72 ; some have no air-bladders, 73
- Fixed stars, conjectures about the, 49 ; their prodigious number, 50 ; and vast distances, 51
- Flat fish, why they keep to the bottom, 73
- Flies, how they walk up perpendicular surfaces, &c., explained, 76, 77
- Fly-catcher, apparatus of the, for taking its food, 92
- Force unable to stop the progress of error, much less that of knowledge and truth, 179
- Foreign or international policy defined, 131 ; nature of international laws, 136 ; the balance of power, 137 ; the rights of nations, *ib.*
- Fundamental lessons in politics, 153
- Galvanism, discovery of, 60 ; improvements in chemistry owing to, *ib.*
- Gastric juice, properties of the, 80 ; different in different animals, 81 ; correspondence between it and the other parts of the body, *ib.*
- Geometrical truths, independent of the properties or even the existence of matter, 25, 26
- Geometry, defined, 18 ; property of the *right-angled triangle*, 19 ; application of this property to the measuring of inaccessible heights and distances, 20 ; the *circle* and its properties, 21 ; the conic sections, 22-24 ; the cycloid and catenary, 25
- Glow-worm, difference between the male and female, 91
- Gravitation, universality of this principle, 48 ; cause of the tides, of the figure of the planets, *ib.*

- Gravity of bodies defined, 41 ; varies as the inverse square of the distance, *ib.* ; the moon affected by gravity, 42 ; its all-comprising influence, 110
- Handicraftsman, the, must not be content to know the rule without the reason, 100 ; first use of his learning the principles of science, *ib.* ; hereby enabled to become an improver of his art, *ib.* ; instances, 101, 102
- Heat, fluidity, and expansion arise from the same cause, 108
- Hexagon, advantage of this figure in filling up a certain space, 73 ; bee's cell of this shape, *ib.*
- Home, Sir Everard, discovery by, regarding the locomotion of insects, 76
- Horse, the, provided with a third eyelid, 70 ; its use and motion, *ib.* ; skilful structure of the limbs of the, 89 ; slanting bones of the foot with their elastic spring, *ib.* ; consequences of unskilful shoeing, *ib.* ; expanding shoe, *ib.*
- Howard, Edward, Inventor of the Process of Refining Sugar, 102
- Hume's Treatise on Politics, the object of, 129
- Hydraulics, defined, 57
- Hydrodynamics, defined, 56 ; divided into three branches, 57
- Hydrostatics, defined, 57 ; fluid pressure proportional to depth, *ib.* ; the paradox, *ib.*
- Hyperbola, one of the conic sections, 24 ; ready way of getting the figure of this curve, *ib.* ; resembles the ellipse and circle in many of its properties, *ib.*
- Ignorance, the cause of tyrants being praised and conquerors applauded, 181 ; the source of human misery and national crime, 182
- Importance of the practical applications of science, 9
- Importance of scientific truths exemplified, 53, 56

- Impregnation of plants, 79
- Imprudent marriages, mischievous effects of, 157
- International law, nature of, 136 ; the subjects of which it treats, 137
- Jupiter, his vast size, 50 ; distance from the Sun, *ib.*
- Jurisprudence, the science of, defined, 136
- Knight, Mr. ; his explanation of the impregnation of plants, 79
- Knowledge, pure pleasures of, 103 ; every one capable of these, 104
- Latitude and Longitude defined, 52 ; mode of finding the, at sea, *ib.*
- Law of Nations defined, 137
- Lever, the, defined, 54 ; its properties and uses, 53, 54 ; why called a mechanical power, 55 ; combinations of levers, 56
- Lichen, the rein-deer's food, in full growth during the winter, 90
- Light, refraction of, 67 ; rays composing white light differently refrangible, *ib.* ; telescopes, 68
- Light, necessary to the growth of plants, 78
- Logarithms, method of, illustrated, 16, 17 ; saving of labour and time from their use in calculation, 18
- Lizards, their power of climbing explained, 77
- Malouet, M., description of an ant's nest by, 84
- Man, the two-fold nature of, 96 ; his senses and their proper use, *ib.* ; his understanding and its refined enjoyments, 97 ; his attributes and position, 143 ; high rewards for the cultivation of his faculties, 144
- Mathematical demonstration, the nature of, and delight afforded by, 111

- Mathematical truths wholly independent of the existence of matter, 25-27 ; depend only on reasoning, 29 ; every link in this reasoning, necessarily and undeniably true 29, 30 ; possibility of discovering these truths without knowing anything of matter, conceivable, 31
- Mathematics, defined, 11 ; divided into two great branches, 12 ; pure and mixed, distinction between, 35 ; pleasures afforded by, in gratifying our curiosity, 107
- Mechanics, the objects of, 53 ; fundamental principle of the science, *ib.* ; the lever and its properties, 54 ; the wheel and axle, 56
- Medicine, objects of the science of, 37
- Mental Philosophy less exact than Physical Philosophy, 124 ; dogmatism to be guarded against, *ib.* ; difficulties of the science and mode of study, 125 ; the intellectual faculties, moral faculties, duties, 95
- Metaphysics, the objects of, stated, 120, 121
- Mind, certainty of the existence of the, 96 ; its refined enjoyments, 97 ; reward consequent on the pursuit of these, *ib.* ; its extraordinary powers illustrated, 113, 114 ; made a subject of observation by few, 126
- Mineralogy, definition of, 37 ; its relation to chemistry, 38
- Mischiefs arising from ignorance of political economy, 157, 158
- Moon, the, proved from observations to be affected by gravity, 41 ; observed also to be subject to the law, which expresses the relation between the periodic times and the mean distances, 42 ; hence her orbit an ellipse, *ib.* ; nature of her surface, 52 ; tables of her motions of the greatest importance at sea, *ib.*
- Moral or Mental Philosophy defined, 11 ; its two great branches, 121 ; the truths of, contingent, not necessary, 122 ; difference between the nature of these truths and those of abstract science, *ib.*



- Moral World, evidences of the, in favour of the existence of an Almighty Creator, 143
- Municipal Law defined, 137
- Natural History, application of this term, 37; defined, 62
- Natural or Physical Philosophy defined, 11; subdivisions of, 36, 37, 120; shown to consist of a mixture of contingent with necessary truths, 123
- Natural Science, some branches of, not to be understood without Mathematics, 61; others need no such aid, *ib.*; some branches useful to particular classes, *ib.*; others easily understood by all, 62; applied to the animal and vegetable world, *ib.*; seemingly wonderful discoveries of, 106; pleasures of, 108
- Nautilus, sailing apparatus of the, 91
- Necessity of having some acquaintance with the Sciences, before a distinct idea can be formed of the pleasures and advantages derived from the study of them, 7
- Necessity of reform and the duty of reforming, 175
- Nepenthes distillatoria*, natural tankards of the, 94; the tankard-lid and its use, *ib.*
- Newspapers, the pleasures arising from the perusal of, 104
- Newton, Sir Isaac, discovers the principle of attraction, 48; concludes that the globe is not a perfect sphere, *ib.*; decomposes white light, 59; instance of his unrivalled sagacity, 60
- Objections to the diffusion of political knowledge stated and considered, 149-170
- Optics defined, 59; composition of white light, *ib.*
- Orbits of the planets, ellipses, 42; irregularities owing to mutual attraction, 45; these irregularities subject to a law of correction, 46; statement of this law, 47
- Ostrich, mode of hatching of the, 91

Palo de Vaca, milk of the, 94

Parabola, frequent occurrence of the, 22 ; its properties illustrated in the doctrine of projectiles, *ib.* ; angle of longest range for guns, fire-hose, &c., 23 ; the curve a section of a cone, 24

Party prejudice, caution against, 164 ; how it is to be allayed, 165 ; apologue of the two knights and the shield, *ib.*

Party violence, evils of, 166 ; to be softened down by education, 167 ; illustrated by the wars of the Roses, *ib.*

Peculiarities of a course of political instruction, 163 ; danger of exciting party prejudice and unkindly feelings, 164 ; this danger not to be suffered to operate against giving such instruction, *ib.*

People more easily governed if politically instructed, 156

Philosopher, meaning of this name, and to whom it is due, 113

Philosophy in its fundamental branches forbidding from the mental effort required for their comprehension, 10 ; but its humblest lessons impart incalculable pleasure, 11 ; further advantages of, 62 ; the object of, to trace unexpected resemblances, 107-109

Physical truths depend entirely on observation and experiments, 31 ; are truths established by mathematical reasoning applied to observed facts, 34, 35

Plants, necessity of light to, 78 ; impregnation of, 79 ; provision made to prevent the male and female blossoms of the same tree from breeding together, 79 ; remarkable instances of design and appropriate contrivance in, 92 ; provide drink and food in parched and desert countries, 93-95

Planets gravitate towards the sun, 42 ; move in elliptic orbits, *ib.* ; perturbations caused by their mutual attraction, 45 ; these perturbations subject to a law which corrects them, 46 ; their diameters, distance from the sun,

comparative bulks and rates of motion in their orbits, 50.

Pleasures which attend the gaining of knowledge for its own sake, 7; their pure, disinterested, and exalted nature, 8, 9; those derived from knowledge, 103, 104; from the discovery of unexpected resemblance, 107-110; from a comprehension of the investigations and demonstrations of science, 110-112; from science in enabling us to trace the evidences of design, of skill, of wisdom in the Creator's works, 115; these pleasures contrasted with those of sense, 116; those arising from mathematical and physical researches, 138; from a knowledge of chemistry, 139; from an acquaintance with the wonders of astronomy, 140; from contemplating the truths of moral science, *ib.*; from an examination of the principles of political science, 141

Pneumatics defined, 57; pressure of air, 58; ascent of water in pumps, *ib.*; ascent of mercury in the barometer, 58; piston in the atmospheric steam-engine, *ib.*: pressure of air exemplified in the locomotion of certain animals, 59

Political arithmetic, meaning of, 134

Political economy, the province of, defined, 133

Political education the only guarantee for peace and justice, 174; the only security against the frauds and mismanagement of statesmen, *ib.*

Political facts universally observed, 126; more obvious than those of mental philosophy, 127

Political instruction, not only necessary, but unavoidable, 167; importance of this instruction being imparted by conscientious teachers and not by unreasoning partisans, 168; the duty of the wise teacher, 169

Political knowledge more generally diffused than moral or ethical knowledge, 127; necessary for, and owing to, the whole body of the people, 175; salutary effects of the diffusion of, 180

Political philosophy most fruitful of all the sciences in prac-

- tical advantages, 146; recapitulation of these, 147; contrasted with physiology and comparative anatomy, 148; objections against teaching this science considered, 149
- Political science, divisions of, 95; definition of, 121; method of getting at the general principles of, 125; its truths more clearly demonstrable than those morals or ethics, 126; facts on which it is grounded, 128; importance of those facts and of those of metaphysical and ethical inquiries contrasted, *ib.*, 129; general view of the science, 130; its two great branches, 131; the diffusion of, beneficial to the cause of good government, 159
- Political truths, evidence afforded by, in favour of the existence of God, 143
- Pollen of plants, nature of the, 79; its globules little air-balloons, *ib.*
- Poor, the; what they suffer, and what they have to learn politically, 154, 155
- Popular ignorance, dangers from, illustrated, 153; often retards measures of government, 160; the cause of commercial restraints and of wars, 162
- Potassium, the properties of, 61, 107
- Practical advantages derived from science considered, 144; notion that these are its only real advantages combated, 145
- Prejudice against the diffusion of political knowledge, 149
- Pressure of air, 59; effects of this pressure, 75; its service to the bee, 76; further illustration of, in the locomotion of animals, *ib.*-78
- Properties of matter learnt by experience, 32; cannot be guessed or deduced from reason, *ib.*; that they might have been different from what they are, conceivable, 33
- Psychology and Ethics defined, 121
- Pure Mathematics defined, 119; excellence of, as an instrument of discovery when applied to observed facts, 123; seldom applicable in mental philosophy, 124



- Public Opinion, the influence of, varies as the government, 171; the people's safeguard, the ruler's curb, 172; its importance under a free government, *ib.*
- Queen-bee, mode of making a, 82; confusion consequent on her loss, 83
- Quills of birds, reason of their strength, 71, 72
- Reading romances, newspapers, ghost-stories, gratification resulting from, 104, 105
- Refraction of light, 67
- Rein-deer, structure of the hoof of the, 90; food of the, *ib.*
- Religious bigotry, illustrations of, 160
- Representative system, the, necessitates a vigilant superintendence by the constituents, 172; important that those who superintend should be enlightened, 173
- Resemblance between the crawling of a fly and the working of the old atmospheric steam-engine, 109
- Retarded motion illustrated, 33
- Right of the people to be instructed in political science, 171
- Right-angled triangle, property of the, 19; applications of this to the measurement of heights and distances, 20
- Risk to the peace of society from the masses studying political science considered, 178; the guarantee is in imparting sound and full instruction, 179
- Safety-lamp, invention of the, 102
- Science and knowledge, difference between, 9
- Science, necessity of to the liberal professions, 98; its utility to most men, *ib.*; to engineers, watchmakers, carpenters, masons, &c., 99; necessity of acquiring the principles of, 100; first use of learning these principles, *ib.*; practical advantages of, 101, 102; pleasures arising from being able to follow out its investigations and demonstrations, 110—112

- Sciences, the, divided into three great classes, 11; distribution of, necessarily imperfect, 37; the branches touch and assist one another, 38; divided into pure mathematics, natural philosophy, and moral philosophy, 119
- Scientific studies, use and pleasure of, illustrated, 96-116.
- Scientific truths important, whether of practical application or not, 146
- Sea animals, their power of climbing explained, 77
- Snipe, bill of the, 92; cause of its sensibility, *ib.*
- Solar system defined, 43
- Solid of least surface, 64; of least resistance, 65; fishes' head, *ib.*
- State affairs, all the community interested in, therefore all should be able to examine, 178
- Statistics, the objects of, 134
- Sugar-refining, the process of, 102
- Supreme power in a state, 135
- Swallow of Java, curious provision of materials for the nest of the, 92; its nest prized as delicate food, *ib.*
- Tapioca tree, pith of the, used as food, 95
- Telescopes, imperfection of, 67; improved by Dollond, 68; and by Blair, *ib.*
- Toucan or egg-sucker, delicate nerve-work of the bill of the, 92
- Trammels or elliptic compasses used for describing ellipses, 23
- Tubes stronger than solid rods of the same length and quantity of matter, 71
- Unequal distribution of power and property necessary for all government, 155
- Unexpected resemblances disclosed by natural philosophy, 108, 109
- Usury, popular prejudice against, 158

## INDEX.

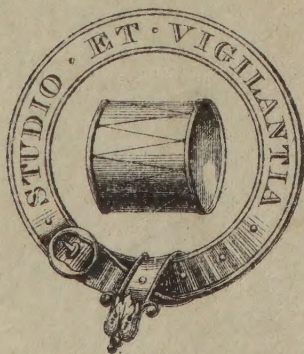
197

- Vanilla plant, use of the tendrils of the, 80
- Virginia creeper, climbing members of the, 80
- Walpole hurried into war by a senseless cry against the Spaniards, 162
- Water, composition of, 139
- Water-with of Jamaica, great abundance of sap in the, 94
- Watt; his improvements of the steam-engine the results of scientific skill, 101
- Wheel and axle, the, shown to be a combination of levers, 56
- White light, a mixture of all others, 106
- Wild-pine of the West Indies, seeds of the, 93; its bag-like leaves filled with water, *ib.*
- Zoology, objects of the science of, 37; its relation to comparative anatomy, 38





EX BIBLIOTHECA



CAR. I. TABORIS.

